# THREE
# LETTERS
## ON
## MINING and SMELTING;

In which a METHOD is laid down,
Whereby theſe uſeful SCIENCES
may be greatly IMPROVED.

To which is added, a Fourth
## LETTER;

Setting forth,
A DISCOVERY of an eaſy *Method* to
ſecure SHIPS BOTTOMS from *Worms.*

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Written by
**DIEDERICK WESSEL LINDEN, *M. D.***

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Humbly inſcribed, by the EDITOR,
To the Right Honourable the
EARL of HALIFAX.

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*Fortuna fidem mutata novavit*
*ſed*
*Res ardua novitatem dare, novis auctoritatem.* PLIN.

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# *ERRATA.*

THE Author being at a great Diſtance from the Preſs, has occaſioned many Errors to paſs uncorrected, therefore muſt beg the indulgent Reader to correct them as he meets with them: The principal are;

*Pape* 17. *l.* 18. for *adapting*, read *adepting*. *p.* 28. *l.* 1. for *bind*, r. *bend*. *p.* 35. *l.* 19. for *ignari*, r. *igneri*. *ditto*, *l.* 26. or elſewhere, for *Slags*, read always *Slacks*. *p.* 38. *l.* 30. for *Slug-ſtampers*, r. *Slack-ſtampers*. *p.* 47. *l.* 17. and *p.* 48. *l.* 14. or elſewhere, for *Mondye*, r. *Mondyc*. *p.* 54. *l.* 20. and 26. for *Opponents*, r. *Component*. *p.* 68. *l.* 21. for *profeſs*, r. *poſſeſs*. *p.* 75. *l.* 14. for *Minior*, r. *Mineral or*. *p.* 76. *l.* 14. for *indicting*, r. *indicating*. *p.* 80. *l.* 2. for *Court*, r. *Coaſt*. *p.* 88. *l.* 2. for *Tales*, r. *Talcs*, and ſo on throughout the Fourth Letter, always for *Tale* or *Tales*, r. *Talc* or *Talcs*. *p.* 89. *l.* 26. for *indeſolvable*, r. *indiſſolvable*.

To the Right Honourable the

# EARL of HALIFAX.

*My* LORD,

I Moſt humbly beg Leave to offer to your *Lordſhip* three Letters on *Mining* and *Smelting*; and a fourth, of a new diſcovered Method of ſecuring *Ships Bottoms* againſt the *Worms*: They were wrote at firſt with an Intention only to ſerve a few Individuals; but, as I thought they might tend to promote the publick Good, and, in Conſequence, concerned the *Nation* in general, well knowing how much your *Lordſhip* makes the national Intereſt your own, I have preſumed, with the Author's Conſent, to preſent them to you for your Peruſal; not doubting, ſhould they appear

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appear in the ſame Light to you, they do to me, but that you will earneſtly endeavour to cultivate the Improvements ſpecified in them, as far as they can properly be put in Execution; of which you are the moſt competent Judge, having already countenanced ſo many important Undertakings, which you have moſt juſtly judged *beneficial* to theſe *Kingdoms*, and for which you have ſo well deſerved of the Publick. I therefore am, with the higheſt Reſpect,

*My LORD,*

*Your* Lordſhip's *moſt obedient,*

*and humble Servant,*

*The* EDITOR.

# THREE LETTERS ON MINING *and* SMELTING, &c.

## LETTER I.

*On the preſent State of Mining in* North Wales, *giving neceſſary Inſtructions for improving it.*

SIR,

I HOPE you will pardon me, that I did not ſooner return an Anſwer to the Queries you have raiſed concerning the Art of Mining; the Delay, I aſſure you, proceeded not from Neglect, Forgetfulneſs, or want of Inclination to oblige you, but my daily Occupations, I may ſay, conſtant Hurry of Buſineſs, before this Inſtant, would not afford me leiſure Time to do it: But now

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I can venture to undertake the Taſk; which I will execute according to the beſt of my Abilities, and the narrow Limits of a Letter will admit.

In the firſt Place, you requeſted of me, to deliver you my Sentiments on the preſent State of Mining, and whether I had obſerved any Improvements of late Years to be made therein: *2dly*, To give you a Definition of the Art itſelf, and of a Mine-Steward; that is, to communicate to you, what Extent of Knowledge a Mining Profeſſor ought to be poſſeſſed with, before he undertakes the practical Part of the Art. 3*dly* and *laſtly*, Whether any Streſs or Dependance is to be put on the *Virgula Divinatoria*.

To anſwer the firſt Queſtion, ſeems at firſt Sight a very hard Taſk; not that the Subject itſelf renders it ſo, becauſe it may eaſily be demonſtrated and illuſtrated beyond all Doubt, that Mining, in this Part of the Globe, is in ſuch a perfect Decay, that it is greatly to be feared, it will, in a few Years, become totally extinct: But the Difficulty ariſes from a Reluctance in me, to expoſe my Neighbour's Inſufficiency, I mean, the Unſkilfulneſs of the Mine Directors, and the Riſk one runs in doing it, for he will certainly be their Mark, and muſt expect to meet with nothing but Contempt and Reproach; he will be as undoubtedly,

doubtedly vilified and proſecuted, as the Friends of the old State of *Rome* were by the libertine and mercenary Senators; nor is it in the leaſt ſurpriſing, for no one of common Capacity can be inſenſible *, as the Author of the Right Honourable *Thomas Winnington*'s Eſq; Caſe expreſſes it, *from what Quarters theſe poiſoned Arrows will be ſhot*; *private Intereſt evidently points out the Aſſaſſins*; *nor is it to be wondered, when the Shrines are in danger, that they ſhould Clamour in Support of their Craft*: Though I would not here be thought to infer, that all of them will become invective againſt me, and ſpirited up by a Paſſion for Lucre; ſome, I hope, are endowed with better Principles; but then thoſe that are, may, perhaps, be biaſſed to ſide with the reſt, through a ſelf Opinion, and for want of being ſenſible, that greater and better Diſcoveries have been made in other Countries, than they are acquainted with; however, the Apprehenſion of bringing Enemies upon my Head, ſhall not deter me from acknowledging an evident Truth, the Deſire of promoting the publick Good, is ever more prevalent with me, than the Fear of Cenſure and Reproach of a ſmall Body of People; I will therefore proceed to comply with your Requeſt with the

ſtricteſt

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* *Vid.* Dr. *Thompſon*'s Caſe of the Right Honourable *Thomas Winnington*, Eſq; Page 6.

ſtricteſt Candour and Integrity; being bound ſo to do by certain Ties of particular Acts of Friendſhip, as well as Service, which you have vouchſafed to confer upon me.

I have told you before, and am ſorry I find myſelf under a Neceſſity to repeat it, that, after the ſtricteſt Enquiry I have been able to make ſince I have been in theſe Parts, and the beſt Judgment I can form from the mineral Hiſtory, I cannot help concluding, that the Art of Mining, ſo far from any Improvements having been made therein, is leſs perfect than it was when firſt it was revived in the Reign of Queen *Elizabeth*; to teſtify the Truth of which Aſſertion, I call upon the Directors or Stewards of the Mines here as Witneſſes, who cannot point out the leaſt Diſcovery made towards the Perfection of it, but muſt confeſs, that a great many uſeful ones have been loſt, as muſt be obvious to every impartial Judge; without farther reaſoning on the Subject, they need only recollect a well known Truth, that our modern Miners do not chuſe to venture their Skill in ſuch Mountains, as are out of the Range and Boundaries of thoſe, where their Predeceſſors made Diſcoveries; nay, they are perfectly amazed, and ridicule the Perſon that affirms, even after the moſt ſolid Reaſons given, that other Grounds contain

Foſſils and Minerals as well as thoſe they work: May it not then be laid down for an undeniable Maxim, that thoſe that firſt made the Diſcoveries, were poſſeſſed of greater Knowledge than thoſe that only trace them, without daring to attempt farther. To witneſs the Truth of this likewiſe, I might call upon many Stewards, who have often confeſſed to me, that the Antients were more verſed in Minerology and Metallurgy, than the Moderns; from whence, and from what I have already ſaid, you cannot wonder, that I infer, that ſome Ages paſt they were more experienced in the Art of Mining, than they are at preſent.

I dare alſo preſume to ſay, that you will readily agree with me, that the Science ſubſiſting amongſt the Miners of our Days is but of ſmall Extent; that the Mines are carried on in an empiric Manner; that all Veins and Beds of Ore are found by ſome lucky Accident, for Shafts are ſunk, and Levels drove at Random, ſo that Mining now is in ſuch diſrepute, that Succeſs in adventuring, is attributed to Chance and Fortune, and Mining deemed a Lottery; for when by the above-mentioned Means nothing is met with, Recourſe is taken to croſs Cuts, and the like expenſive Experiments, till at length the Proprietors, being tired with fruitleſs Eſſays, the whole Blame is laid upon the poor defenceleſs Mountain, which is looked upon as barren, and unnaturally robbed of its Character, though, to all after Ages, it ſhews the ſtrongeſt Symptoms of its being the Repoſitory of uſeful Foſſils and Minerals. *Sic terræ perduntur opes.*

But let us take a View of the Method of Mining uſed in the more primitive Times; let us examine what we find upon Records concerning it; let us caſt an Eye upon the Remains of their Works, which to this very Day bear the Name of *Roman* Works; by theſe we ſhall find, that they never digged for any other Veins, than ſuch as diſcovered themſelves on the Surface which they worked, as at this Time Ditches and Trenches are made in Camps, and ſo laid the whole Vein open; for they knew nothing of ſinking Shafts through hard Rocks, as we are obliged to do at a very great Expence, they were unacquainted with the Tools now in uſe, Whimſies, Fire-engines, and all Sorts of Machines for draining of Pits, were not then invented; ſo when they diſcovered Veins on the Sides of the Mountains, they worked them by Levels, but in no Shape in a workmanlike Manner, comparatively to what they do now in *Sweden* and *Germany*; nor did they follow them any farther than they continued ſoft and mild, deſiſting as ſoon as they came into any hardneſs, and leaving the reſt for Poſterity; they indeed contrived and erected Baths, and made Conduits and Reſervatories for Waters with great Ingenuity, but theſe have no Reference to the Art of Mining; nor do I find in any of their Annals, that they diſcovered any Mine by thoſe Means. Now, as in *Wales*, they in ſome meaſure labour under the ſame Difficulties with the *Romans*, it is incumbent on them to reduce the Art of Mining into a rational Syſtem, as they have done in ſome foreign Parts.

It muſt then be allowed, that the Antients had greater Advantages than we have, and in particular of finding Ore ſo near the Surface, which they could likewiſe raiſe at a much leſs Expence than we can now-a-days, having Slaves to do it, whereas now the Hire of Labourers, and the Wages of Workmen, make up great Sums; nor is it to be wondered at, for every thing that depends upon the Hand of Man, muſt undergo prodigious great Changes in the Space of 1000 or 1500 Years.

From this, and a due Conſideration of the great Diſadvantages, which, in Compariſon to them, we labour under, it will evidently appear, how highly incumbent it is on us to extend our Thoughts a little farther towards making Improvements in this uſeful Science; for which Purpoſe, Providence has evidently given us her Aſſiſtance, and afforded us all the requiſite Means for effectually accompliſhing it: As for Inſtance, the Antients were ignorant of the Method of working ſtubborn Rocks by the help of Fire, which the *rational Moderns* are very well acquainted with, I mean ſuch Helps of Fire as are not included in blaſting; but when firſt Neceſſity obliged us to ſink and drive through hard Beds of Stone, and penetrate deep into the Mountains, in order to ſupply our want of Foſſils and Minerals, Gun-powder was accidentally diſcovered; a great Improvement indeed, and a neceſſary Utenſil in all Arts where firing is required; it therefore came to be introduced into the Art of Mining, where it is of ſuch infinite Service, that, for my Part, I do not know how we ſhould ever be able to come at the Ore of any mineral Vein, were we deprived of the Benefit of blaſting.

From a tranſient View of theſe Circumſtances, it will readily appear, how much the late Diſcoveries have contributed to aid us in the Improvement of Mining, and how little the Advantages are which in theſe Parts are reaped from them; it is equally as evident, that, for want of theſe Aſſiſtances, the Primitives could not claim an Equality with the rational modern Miners, whereas, in this Country, they cannot

not greatly challenge the Superiority; but the Ignorant, like the blemiſhed in Character, are ever ſeeking out for an Aſylum, which, if they can no where elſe meet with, they ſhelter themſelves under the Merit of their Anceſtors, which, I am afraid, is too much the Caſe here in *Wales*.

Now let us proceed to your ſecond Requeſt, and ſhortly point out what a Mine Profeſſor ought to know, before he enters upon the practical Part of this Science.

Firſt, he that would aſpire to be a Maſter Miner, muſt be acquainted with that Part of natural Philoſophy called Chymiſtry; after which, he muſt repair to the Mountains, viſit the Mines, and daily go under Ground, that he may ſee the common labouring Part, and the different Methods of working, make himſelf familiar with the different Strata of Earth, Stone, Rocks, Minerals, Foſſils, and metalline Veins, paſſing over nothing that bears the leaſt Analogy or Affinity to Minerals, or that can give him the leaſt Inſight into the Art of Mining; he muſt alſo be very inquiſitive with the Miners, and examine them ſtrictly as to what different Things they meet with in their Way, hear what they like beſt, and what they look upon as the moſt promiſing Symptoms of coming into Ore, its Duration, or the contrary;

for though they are ignorant of the natural Cauſes of Things, and cannot give a Reaſon why ſuch and ſuch a Sign is promiſing or otherwiſe, and through this Deficiency are not capable of delivering their Accounts in a regular methodical Manner, yet we may be able to order them to our Advantage, and deduce the rational of them to our Improvement: Having thus far arrived, we muſt next proceed to that part called Minerology.

This ſome take to be the firſt Rudiment, and grand Baſis, or Ground-Work, on which the Art of Mining chiefly depends, * be that as it will, I conceive this Science will be more eaſily comprehended, after having acquired a ſufficient Knowledge of what I have propoſed in the above Paragraph. Therefore, that no one may be at a Loſs to know what Minerology is, I will define it to be a Science, which teaches us the Principles of Minerals, and learns us to diſtinguiſh the ſeveral Kinds of Ores from each other; this Science I will here divide into two Parts, about the Firſt our Senſes alone are employed; we are therefore diligently to examine all Foſſils and Minerals, as they appear to the naked Eye, when freſh collected, whether in a perfect ſolid State, which then go under the Name of

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* *Vid.* Dr. *Zimmermen*'s Preface to Dr. *Henkel*'s Leſſer Minerology, publiſhed in the *German* Language.

of Virgin Ores; or in a glimmering, ſhining, friable State, or in a Mixture of ſeveral different Things with one Metal, or Semi-Metal, the reſt being Earth, Spar, Stone, Chirk, and ſuch like; and when they appear intermixed, in what Condition they are, and what has the Predominancy: We muſt alſo, with the ſtricteſt Scrutiny, weigh the ſeveral Degrees of Exaltation in them, their peculiar eſſential Dignities, and moſt remarkable Properties, which we always meet with different, in different Ores. Some denote their Eſſence by their Colours, by which they may be eaſily diſtinguiſhed, becauſe Chymiſtry maks us acquainted with their peculiar Appearances, ſhewing us why ſuch and ſuch a Colour, is peculiar to ſuch and ſuch a Foſſil; ſome we are to frame our Ideas of, by being interwoven or intangled with other Bodies, ſome being Homogenious, others Heterogenious to them, the former of which always tends to their Preſervation, the latter to their Deſtruction; by this Means we ſhall have as ſufficient Teſtimony, as we can deſire of the Maturation, Perfection, and Decay of the ſubterraneous Wealth; but it muſt be in particular recommended, that every one makes his Collections with the utmoſt Diligence and Regularity; here I apprehend that an Objection will be raiſed, that this Branch of the Science, called Minerology, is a very extenſive one, not adapted to the Genius of thoſe, who chuſe not to ſpend their whole Days in one Branch of Literature; I do admit, that there is no End of making Collections of Foſſils, and the ſupreme Head is much to be admired, that he has created ſuch vaſt Variety; how otherwiſe would our curious Succeſſors be entertain'd in after Ages, if Limits and Boundaries were admitted; but altho' a Man's Capacity may be employed, *ad Infinitum*, yet a diligent Student will ſoon furniſh himſelf, ſo that he may be able to appear with ſufficient Applauſe in the Mineral Kingdom.

Further it is to be obſerved, that all that I have refer'd to the Scrutiny of the naked Eye, ought to be inſpected by the Help of magnifying Glaſſes, and ſo for the firſt Part, enough at preſent.

The ſecond Part of Minerology conſiſts in examining thoſe Foſſils, by the Help of Chymiſtry, which we cannot obtain a perfect Knowledge of, by their outward Characteriſticks, or by a bare Inſpection: This Examination muſt be performed in ſuch a Manner, that the whole Body may be ſtrictly ſaid to be anatomized, by reducing it to its component Parts or Elements, each Content of the Mixture, or Compound muſt be produced by itſelf, in its juſt Quantity, and due Quality, taking care that none of its Principles are deſtroyed in the Operation, but that every Individual be ſeparated from each other, and made to appear in its true natural State, and that in the ſtricteſt Senſe: Under theſe Examinations, not only Mineral Ores and Foſſils are to be taken, but all ſorts of Earths, Salts, Bitumens, Stones, and whatever elſe the Mineral World produces from its Surface, even to its inmoſt Receſſes, are in like Manner to be eſſayed. The Method alſo of Smelting Metalline or Mineral Ores, by the Help of large burning Glaſſes, comes under the Science of Minerology. In fine, it is not adviſable to ſtop here, till we have acquired a perfect Knowledge of all the different Strata or Layers of Earth, Stone; in ſhort, of all the Contents of the Mountains, even a *Summo ad Imum*; hence we learn, what is peculiar to every particular Metal, and how each Mineral affects its neighbouring adjacent Rock, Stone, Earth, or whatever elſe lies contiguous to it, which with Diligence and Labour, we can arrive to a certainty of, by the Help of Chymiſtry, for the Exhalations ariſing from Mineral Bodies, tinge the whole even to the very Surface; ſo that it is not any way ſurpriſing, that a Skilful Minerologiſt, by a bare Survey of the outward Soil, can determine what Mineral or Foſſil is contained underneath.

Some, and in particular the moſt learned Dr. *Zimmerman* will have it, that Metallurgy ſhould immediately follow Minerology; * but I conceive that the moſt rational Way would be to make a compleat Miner, before we think of a Smelter; therefore I ſhall not follow him, nor introduce in Metallurgy here, inconſiſtent with Regularity and due Order, for the Latter ought to begin where the Firſt ends; I will therefore give you my Thoughts on that, in a particular Letter by itſelf, in which I ſhall not forget to ſatisfy your Deſire of knowing what Service Metallurgy is to the Miner, to make him form a true Judgment of what he gets by his Labour, ſo at preſent I will proceed to the

Third Branch of this Science, which is Subterraneous Geography, or a Deſcription of the Mineral Kingdom; this offers to our View, Veins, Beds, Strings, Bags, Bellies of Ore, and all Minerals; but in the Study of this, we muſt firſt Survey the Slopes or Swallows termed by the Miners Veins, juſt as they appear to the naked Eye on the Surface of the Mountain. *Secondly*, Particular Regard is to be had to the Veins, Strings, *&c.* *&c.* in reſpect to their Situation, that is, we muſt diligently examine them as they lie in their natural

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* Dr. *Zimmerman*'s Preface to Dr. *Henkel*'s Leſſer Minerology.

State, obſerving their dipping, heading, *&c.* *Thirdly*, We muſt ſee in what Manner the Minerals that comes under our Hands were found, whether in Veins, Beds, *&c.* whether on the Top or Sides of the Mountain, deep in the Ground, or near the Surface, and in what Manner they are joined to the different Strata of other Bodies; thus ſingle Veins and Beds of particular Minerals are examined in Minerology, but in Subterranean Geography we muſt not ſtop here, all Mineral and Metalline Rakes of whole Mountains, comes under our Inſpection, each and every one is carefully to be examined; to do which effectually, we muſt diligently obſerve in what Manner it joins to the other Hills, that appear on the Right and Left, or on both Sides of it, weighing their Regularity or Irregularity, Contiguity and Reſemblance to each other, the Situation of their Veins, in reſpect to the Poles, is to be taken Notice of, whether they run Eaſt and Weſt, or North and South, always placing the Meridian from ſome other rich Vein or Mineral Hill, not forgetting to take a View of the neighbouring and adjacent Vales and Dingles; after this is done, we muſt proceed to the Earth and Stone, for theſe require our Attention, to ſee how they are cloſed and ſtratified; all appearing Strings, by Slope or Fall of Ground, muſt be taken Notice of, and where they join with the main Rake, is deliberately to be conſidered, nor are the appertaining Springs and Rivelets to be ſlightly paſſed over, for from their Origin and Courſe, we may judge; nay, oftentimes have evident Tokens, whether they have the Vein we are in purſuit of, dry or otherwiſe; neither are the Herbs that grow upon the Veins to be neglected, which it will not be amiſs Chymically to Analize, that we may ſee what Mineral Subſtance they partake of, for they always imbibe ſome Effluviums that ariſe from the Veins or Beds; of all theſe Particulars, Draughts ſhould be taken, and proper Annotations or Remarks annexed to each of them, for theſe will be neceſſary to eſtabliſh Memorandums for every Individual, he that is ſo far well verſed, cannot be unacquainted with the outward Mine, or Ore-bearing Symptoms, he may therefore begin to frame his Judgment, but before he is deciſive in the Undertaking, he muſt, *Fourthly*, Examine the Places where we apprehend the Veins and Strings to be, with the *Virgula divinatoria*, by this we muſt determine how far we are from the Mineral we are in ſearch of, what Obſtacles we may meet with, how we may be impeded by Rocks and Water, before we can come at the expected Treaſure; from whence the Facility or Difficulty of the working Part is to be decided, which I ſhall directly proceed to, leaving the *Virgula Divinatoria* to the Cloſe of this Epiſtle.

*Fifthly*, This Branch of the Art may be juſtly termed the mechanic Part, which every Mine Profeſſor lies under an indiſpenſable Neceſſity of being acquainted with, before he preſumes to undertake the Direction of a Mine; for ſhould he, that thoroughly underſtands the riſing, heading, dipping, *&c.* of a Vein, with what I have ſaid above, be ignorant of the beſt Method of working it, whether by ſinking, driving, blaſting, *&c.&c.* No! on the contrary, ſhould not he render himſelf verſed in all the common labouring Part? Certainly, by all Means, that he may be capable of directing and adapting each different Method to the different Circumſtances and Nature of the Place; and not be obliged to ſuffer the ignorant Labourer to go on in his own Way at Random, who perhaps, indeed, by a round about Road, may come at the Ore at laſt; but how often are they miſlead? What great and fruitleſs Expences have they not occaſioned by their blind and uncertain Way of proceeding? Nay, how many Works have been intirely ruined? And how many Places, for a Time, forſaken, which afterwards have been found to yield great Quantities of Ore to conſiderable Profit, though firſt miſſed through the Ignorance

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of the Workmen, thus ſuffered to go on in their own Way? Therefore, undoubtedly, you will not diſagree with me, in pronouncing the ſhorteſt and ſureſt the beſt: I have ſaid above, that the Mine Profeſſor ſhould be well verſed in the mechanic Part of Mining; he muſt therefore know when he has Occaſion for Timber, and what Sort; and, where Timber cannot be had, how to ſubſtitute Brick-work, or Maſonry, in order to gain his Point, and to arrive at the Ore he is in ſearch of.

*Sixthly*, A Mine Director muſt be well acquainted with all the different Machines uſed to drain off the Water with which the Mine may be overwhelmed, that he may be capable of ſelecting ſuch as are moſt fit and neceſſary for his Purpoſe, when a ſufficient Level cannot be had: The known Improvements that have of late been made in this Branch of the Science, are very much wanted in theſe Parts; there are indeed Fire-engines, and ſuch Utenſils erected, which are very deſervingly called Whimſies; but their Expenſiveneſs is ſo great, that they ruin and deſtroy many beneficial Mines: Improvements therefore cannot be too ſoon attempted; which, I am very well convinced, might be made with the greateſt Facility; but the Boundaries limited me, will not permit me here to expatiate on this Subject, and point out in what Manner they are to be done.

*Seventhly*, He that preſumes to take in Hand the Direction of a Mine, muſt alſo be a perfect Maſter of ſubterraneous Geometry, or the Method of Dialling, that he may meaſure Shafts, contrive Levels, &c. &c. to the beſt Advantage, that he may be able to come at the Ore as deep as poſſible. This Art, however, is pretty well known here; nor do thoſe a little Glory themſelves upon it that are Maſters of it; which, though I allow to be of great Uſe and Service, yet ſuch great Streſs is not to be laid upon it, as ſome of our reigning Stewards would make appear, and too much over-rate themſelves upon; for ſubterranean Geometry is to Miners, what Latitude is to ſea-faring People; whereas ſubterranean Geography is to our Art, what Longitude would be, was it diſcovered, to that of Navigation; or, the Parallel may be more ſtrictly and plainly drawn, betwixt the Geometrician and Anatomiſt; the one only knowing the Diſtance and Dimenſions on and within the Place he is ſurveying, whilſt the other comprehends not only that, but all the inward Parts of the human Body he is handling.

*Eighthly*, A Mine Student muſt alſo not forget to make himſelf Maſter of removing and expelling the ſtagnating vitiated Air out of the Mines, commonly called Damps, by Rarefaction by Fire, and by ſuch alkaline and volatile Medicines as are oppoſite to the heterogeneous Matter; ſome Specimens of which, may be ſeen in my Letter on Mining to Mr. *Hooſon*; theſe will precipitate the thick, terreſtrious, and mineral Particles, and give a free Vent to the Air, which, by Stagnation and Preſſure, hindering a free Exhalation through the Cavities of the Rocks, are the real Cauſe of theſe pernicious Qualities. But, whatever Medicines are made uſe of for this Purpoſe, it muſt be remembered, as I have juſt above ſaid, that Choice is to be taken from that Claſs that conſiſts of Parts as diametrically oppoſite as poſſible to thoſe that cauſed them; which being of the acid Kind, Alkalies are not to be queſtioned; 'tis therefore that Quick-lime is often made uſe of for this Purpoſe with good Effect; which, though not a real Alkali, yet is of the ſame homogeneous Nature, and near a-kin to one; but volatile Alkalies have always the ſureſt Effect; for which Reaſon it is, that I chuſe to ſtick by them, particularly as they may be had at an eaſy Rate. In fine, by whatever Means they are conquered it matters not; for when that is once done, the like Effluvia, the Preſſure being taken off, will perſpire or exhale uninterrupted,

interrupted, without prejudicing the Workmen.

*Ninthly*, A Mine Director muſt know the different Methods of Ore dreſſing, and waſhing by Stampers eſpecially, that he may be a Judge when it is made fit for the Smelter; all Minerals and Foſſils require it, for, till that is done, they are not merchantable, or ready for the Furnace; becauſe, when they are firſt taken out of the Caverns of the Earth, they are intermixed with heterogeneous Matter, which muſt be ſeparated from them, before they are fit to undergo the Fire; ſo, they are not miſtaken, who affirm, that Metals, Minerals, *&c.* *&c.* are conceived with the Seed of Corruptneſs as well as Men. This Branch of the Art, in this Part of the Kingdom, calls aloud for a Melioration, which might eaſily be effected, conſidering the many Rivulets that offer their Service in being inſtrumental to it; on theſe, Stampers might be erected, whereby the whole Waſte might be dreſſed and cleaned, without being at the Trouble and Expence of waſhing it five or ſix Times over, as I have often ſeen it done in *North Wales*, to my great Regret. They have indeed Stampers at ſome Smelting-houſes, by which they clean their Slags; but even thoſe might be improved to conſiderable Advantage; ſuch Things as theſe belong to the mechanical Part of Mining, which it cannot be expected will come in vogue here, unleſs ſome one takes upon him to inſtruct the Inhabitants, by particular Draughts, in what Manner ſuch Machines are to be erected; which being done, they would ſoon conceive, and come into a true Notion of them; by this Means, in a ſhort Time, a Number of Mine Utenſils would be introduced into Practice.

*Tenthly*, As a Mine Profeſſor ſhould at the ſame time be a Metallurgiſt, ſo he muſt in courſe know the Nature of Iron and Steel, and be, conſequently, capable of inſtructing his Smith how to make the Tools, which muſt be differently adapted to different Kinds of Ground through which they are to cut: Thus, for Inſtance, Tools that are tempered very hard with Steel, are not ſuitable to Gravel, Earth, and ſoft Limeſtone; but ſuch are neceſſary, when it is required to cut through Hardneſs; but after whatever Manner they are temper'd, or of whatſoever Sort they are, it muſt be ſeen, that they are always kept in good Order; for bad Tools make waſte and cauſe unclean Work.

*Eleventhly*, Sometimes in the Purſuit of Metals, we meet with ſuch Things as we did not expect, as Antimony, Zink or Spelter, Biſmuth, and many other uſeful Foſſils, whereby the mineral Manufactory may be improved;

proved ; therefore the Director of the Mine muſt be always upon the Watch, or ſhould charge his Workmen, if they light with any thing uncommon, immediately to inform him of it, leaſt ſomething ſhould be thrown away which might be turned to the Advantage of the Proprietors ; it is for this, and many other Reaſons, evident, that the Director ſhould be both a Minerologiſt and Metallurgiſt.

I might here expatiate on the required Knowledge of a Miner much further ; but becauſe, in the above Articles, I have enumerated the principal Branches of it, I will at this Time ſpeak no more of them ; for he who is well acquainted with what I have already laid down, cannot be ignorant of what I have omitted: I will therefore promiſe him, if he be but diligent in his Searches and Employment, that his Endeavours will be crowned with Emolument, for his Labour he will deſerve well of the Publick, and the Works that he has under his Care, will flouriſh as much as the Nature of them will admit. But if a total Reformation in the Art of Mining is expected, I muſt ingenuouſly and plainly tell you, that it cannot be brought about by a few; the Nature of the Attempt plainly manifeſts, that the major Part of the Proprietors muſt agree, and enter into a Coalition, before it is ever taken in Hand, or at leaſt effected; therefore I can promiſe myſelf nothing elſe from theſe my Endeavours, then that they will be rendered ineffectual. However, I may live in Hopes, for ſometimes great Things have but ſmall Beginnings; and wiſh that they may not be fruſtrated, which I ſincerely do; as likewiſe, that our Stewards, who in this may ſee in what they are deficient, being prompted by Zeal, may ſoon attain a true Knowledge of their Profeſſion.

Now I will proceed to the third and concluſive Part of this Letter, and tell you what Dependance is to be put upon the *Virgula Divinatoria.*

The Hazel-Fork is commonly taken for the intire *Virgula Divinatoria*, but erroneouſly: Indeed, I muſt confeſs, that it is not to be wondered at, that this moſt uſeful Implement for diſcovering Mines, is ſo much doubted of in theſe Parts, as by moſt to be deemed a downright Chimera, and reckoned under the *Non-exiſtentia*; for which, however, I can partly account, becauſe the Knowledge of this Inſtrument has either been in the Hands of ſuch as had not Leiſure or Ability ſufficient to reduce the Uſe and Knowledge of it into Writing; or elſe they were ſo tenacious of it, that rather than ſerve their Poſterity or Fellow-Creatures with it, they choſe, through Exceſs of Avarice, to conceal it, as much as in their Power lay; of which I could produce many Inſtances, ſhould I not draw this to ſuch a Length, as to make it exceed the Bounds of a Letter.

They, however, that are in Poſſeſſion of it, labour under one great Diſadvantage, I ſhould rather ſay Impediment, which is, that it is hardly poſſible to tranſmit the Knowledge of it in Writing; as for my Part, I would not take the Task upon me, leaſt I ſhould fail in the Attempt; but of this I am certain, for by Experience I know it, that I could inſtruct a cúrious rational Mine Student, ſo as to make him Maſter of it by the Dint of Practice; for by Practice chiefly muſt every Man come to underſtand its uſe.

For one Thing I blame our Adverſaries of the Divining-rod very much, but particularly thoſe that pretend, and actually have, ſome Tincture of the Philoſopher, and ſome Sketch of Knowledge of the abſtruſe Myſteries of Nature, that they ſhould turn their Ridicule, and exerciſe their ſatirical Wit, upon the poor Hazel, is to me amazing, as if there was no Connexion or Affinity between Vegetables and Minerals; which, though with an aſſuming Air of Certainty, they pronounce there is not, is only juſt as right as it is true, that the forked Hazel is uſed as a Magnet by itſelf, but both are abſolutely falſe. How much then is it to be lamented, that Men of Authority, whom Fortune has favoured with Plenty and Riches, Providence endowed with ſtrong natural Parts, Leiſure afforded all Opportunities of improving, and Nature lent a laudable Curioſity ; is it not to be lamented I ſay, that ſuch ſhould condemn the moſt ſacred Truths of Nature ? But whether they that oppoſe them, do not in the End ſuffer and prevent the Utility of their Fellow-Subjects, I ſhall leave every thinking Perſon to judge.

No Naturaliſt can deny the near Analogy or Affinity there is betwixt Minerals and Vegetables, when it is well known, that even in ſome, the very mineral Principles they partake of may be diſcerned by the Taſte ; as for Inſtance, all the Products of Oaks, even the Bark and Wood itſelf, the green Shells of Walnuts, Pomegranates, and others of the like Kind, ſtrike ſuch a ſenſible mineral Guſt upon the Palate, that he muſt be deprived of the Senſe of Taſte, or obſtinate to the laſt Degree, that will not confeſs it : Does not again the Peruvian Bark, that grand Specifick in Agues and Intermittents, derive its medicinal Qualities from ferruginous or irony Particles ? So that I am convinced, that the late diſcovered Preparation of Steel, which ſo remarkably has diſtinguiſhed itſelf for the Cure of ſuch Fevers, will ſoon out-rival it; but why ſhould I ſpend my Time in proving the Analogy betwixt Vegetables and Minerals, ſince *Becher* has ſo fully done it in his *Phyſica Subterranea*, and many others ſince him.

But I will leave their Authorities with the Senſe of Taſte, which may be deceived, ſince Experiments have put the thing out of doubt, by extracting perfect Metals out of Vegetables, as I have done Iron out of ſeveral *. *Becher*, in the ſecond Page of his *Metallurgia*, informs us, that he has ſeparated pure Gold from Grapes that grow on the Range of Gold Mines in *Hungary*, and that he afterwards drank the Wine that was made of the ſame Growth. This is likewiſe confirmed by *Jacobus Lupinus*. *Cluverus* tells us, that Tin has been taken out of Broom. Numbers of other Examples might be brought of the like Nature, but I think theſe ſufficient; what then can our Adverſaries alledge againſt ſuch Teſtimonies? Why ſhould they any longer deride and upbraid me, when I aſſert nothing but what is conſiſtent with the Dictates of true natural Philoſophy?

Thus we ſee, that Vegetables contain a Magnet which attract the metalline Parts of Minerals in the very Action of their Growth. Is it then ſurpriſing, that vegetable Forks ſhould bind themſelves in our Hands, when we come upon mineral Veins, and Beds of Ore, as undoubtedly they do, as ſoon as brought within the Reach of their Effluvia ? Certainly not at all! but that is not of ſo great Satisfaction, nor does it make ſo much to our preſent Purpoſe; for though they act thus far, yet they do not deſerve the Title of Divining-rods, becauſe, by the ſingle Hazel or vegetable Wand, though it is attracted, yet we are not able to diſtinguiſh by what corpuſcular Effluvia the Attraction is cauſed; therefore cannot judge what Mineral is under, nor how deep it is from the Surface, nor what Impediments are betwixt us and the attracting Body; therefore ſomething elſe is required to compleat the Divining-rod, and to give us a competent Knowledge of what we are about. The Hazel Fork then is only the Vehicle on which the Magnet for different Metals is to be fixed; and the Hazel is choſen on account of its containing not ſo many of the ferrugenous Particles as other Vegetables do, this being the only Reaſon why it has the Preference.

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* See my Treatiſe on the Origin, Nature, and Virtues of Chalybeate Waters, *Page* 237.

As to the different Magnets for the different Minerals, artificial ones are commonly made uſe of, which, how to prepare, Nature herſelf dictates and inſtructs us. For let the Effluvia of any Mineral be collected in a proper Vehicle, and for that Species your Magnet is compleated, the Quinteſſence of Bitumens, ſuch as are obtained from *Barbadoes*, Tar, Succinum or yellow Amber, and ſuch like reſinous Foſſils, have for many Generations been made uſe of, as Receivers of the metalline Effluvia, in order to be rendered magnetical and fit for our Purpoſe; but of late, Zink or Spelter-aſhes have been found more ſuitable.

Theſe being the neceſſary Ingredients for preparing the Magnets, the clean mineral Ores muſt be taken as ſoon as they come out of the Earth, for the Air renders them unfit for the Purpoſe; and their Effluvia forced into the Receiver, obſerving what I have ſaid before, that every Mineral or Ore produces its own Magnet: Thus, for Inſtance, ſuppoſe you would make a Magnet for Lead Ore, you muſt take all the different Species as can be got, as Silvery-white, Steel, Dice, in ſhort, whatever Sort the Country is known to produce; the middle Parts of which are the beſt, as being the leaſt expoſed to the Air, and the moſt free and clean from Earth, which muſt always be ſeparated, but not by waſhing; for the Earth with which it is entangled, is not of the ſame immediate Genius with the Ore; theſe are all to be powdered, livigated, and put into Aludels, or ſuch chymical nſtru-

Inſtruments, as will convey the Effluvia to the Quinteſſence of the Bitumens or Zink-aſhes; forcing them ſo long with a continued Fire, till the Maſs becomes a ſtony Concrete, which will be the Magnet.

This Magnet is to be fixed to the Hazel Fork, and then tried upon the Places where the Vein is ſuſpected to lie; and if there is any, by properly guiding, turning, conducting, *&c.* the Machine, the Effluvia will be cauſed to aſcend as out of an electrical Body when electrified; which will communicate ſuch an Impulſe or Motion to the Magnet, that the skilful Minerologiſt may be able to frame his Judgment with ſufficient Certainty.

But this I muſt recommend, above all Things, that no one attempts to aſpire to the Knowledge of this *quoddam indicans ſeu Divinatorium,* that is not perfectly well verſed in Minerology or Metallurgy; for if he does, he will be certainly foiled in the Effort, and meet with the Fate of *Icarus*, who, as *Ovid* relates in his Flight from *Crete*, neglecting the Advice of his Father, by going out of his Road, and aſpiring too high, fell into the Sea; but, if he is Maſter of theſe, he may proceed to learn what I have juſt now been ſpeaking of, by a rational, but not an ill-grounded Theory; by a conſtant, but not a ſuperficial Practice; taking care that he plunge himſelf not into the Abyſs of imaginary Hypotheſis, with which this Science is overwhelmed, and too many of its Followers are infatuated; but let him be cautious in determining, and not hurried away by too early appearing Symptoms, but prudently and patiently wait till all promiſing ones concur, which he by Experience has found to be plainly Indicants.

For Reaſons already alledged, I chuſe not to undertake the Task of deſcribing how the Magnet is to be uſed; though I ſhall not be averſe, but, on the contrary, always willing to inſtruct ſuch mineral Students, in whom I find a proper natural Capacity, bent to ſuch philoſophical Inquiries; and will give them all the Aſſiſtance that is in my Power, provided I have no other Objections againſt them.

Thus, Sir, I hope, to your Satisfaction, I have anſwered all your Queries, and executed the Task you have done me the Honour to impoſe upon me. The Roughneſs of ſome of my Expreſſions, I deſire you to be ſo good as to excuſe, which you may perhaps think ſomething harſh and ſevere; but, as I have uttered them neither out of Ill-will or Malice to any, but through a Zeal for the national Good, and a Deſire to let ſuch as are in a manner totally unskilled in Arts and Sciences, ſee they are not fit People to undertake the Direction of the Mines, which they, by working a little in, and accidentally meeting with ſome good Luck and Fortune, think themſelves as ſufficient for, as the moſt learned and experienced Judges poſſibly can. Who am,

*SIR,*

*Your moſt obedient Servant,*

DIEDERICK WESSEL LINDEN.

Holywell, *in* Flintſhire,
Aug. 18, 1749.

LETTER

# LETTER II.

## *On the preſent State of Smelting, and by what Means it is to be improved.*

SIR,

IT appears, from the moſt authentic Account of the Generation and Production of Men and Things, that *Smelting* may juſtly claim the Preheminence of almoſt all other Arts and Sciences; for God, after the Expulſion of *Adam* out of the happy Abode, in which he was firſt delightfully ſituated, immediately made him acquainted with the Uſefulneſs and Benefit of Cloathing; ſo, neceſſary, for the Preſervation and well being of human Nature, in the corruptible State he was then oblig'd to exiſt in; ſo as he was deſtinated to till the uncultivated Land for his Support and Suſtenance; we may reaſonably conclude (tho' it is not particularly mentioned in that brief Hiſtory) that he was made acquainted with Iron-Ore, and the Method by which Iron was to be made out of it; otherwiſe it would have been morally impoſſible for him to have perform'd the Task appointed him; therefore we cannot reaſonably believe, that God neglected to give him Inſtructions, and to furniſh him with proper Means for obtaining the more neceſſary Part of his Subſiſtence, when he had taken ſo much

Care of the Leſſer, as is before ſpecified; eſpecially as his change was ſo ſudden and immediate, as well as ſo exceeding different and grievous; beſides, this appears to be the real State of Things, by erecting Altars, preparing and performing Sacrifices, building Cities, *&c.* even in the Life-time of *Adam*, and by his Deſcendants being ſo early acquainted, if not then, at leaſt very ſoon after, with other Inventions and Materials ſerving for Profit, as well as Delight, of human Nature, under the preſent Circumſtances of its Exiſtence in this World; of which there are many Particulars related in that Hiſtory; but, becauſe many of them have been already taken Notice of by Writers on this Subject, I ſhall only mention two of them; the firſt is, that famous chymical Proceſs perform'd by *Moſes*, in reducing the *Golden Calf* into Powder; and the other is, that recorded amongſt the many Bleſſings, which God beſtow'd on his favourite People, the *Iſraelites*, which he aſſur'd them they would meet with in the promiſed Land; which, in the Original, is thus expreſs'd, *That it ſhould be a Land, out of whoſe Stones they ſhould make Iron, and out of its Mountains dig Ore*, Deut. *chap. viii. ver.* 9.

I apprehend it needleſs, and quite foreign to my preſent Deſign, to entertain you with a long Digreſſion of what Changes the Art of Smelting has undergone from Time to Time, and to tell you how it has been tranſmitted from one Nation to another; but this as an undoubted Fact, muſt be allowed by all, that the *Germans*, for more than three Centuries paſt, with an unwearied Study, and with the utmoſt Diligence, have applied themſelves to this Art; and what Improvements have been made therein, eſpecially in the Space of theſe laſt Hundred Years, evidently appear from their Writings, which ſhews they have far exceeded every Thing, that has been perform'd by thoſe of all other Nations put together. In other Places, Smelting has been only periodical; and *Van Helmont*, was not miſtaken, when he ſaid, *Græci tantum Alphabetarii, reſpectuque Germanorum Ignari, quicquid veteres de re Metallica edidere.* *

It is a received Opinion in Hiſtory, that the *Romans* ſmelted Ores in this Kingdom, particularly in *North Wales*, which is founded upon the Slags, which are ſometimes digged out of the Hillocks here; but then theſe Slags are Demonſtrations of their Unskilfullneſs in the Art of Smelting.

But, let us return to later Times, and examine the *Hiſtoria Metallurgiæ*, or the Traditions concerning Smelting; theſe give us to underſtand, that, putting aſide the

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* *Tractat. de Lithiaſi*, Chap. viii.

Age in which the *Romans* inhabited theſe Parts, it is not above ſixty Years ſince the Art of Smelting was revived in *Flintſhire*; nor do I find any Works erected before that Time; therefore they cannot be ſaid, but to be of a very late Date here.

According to *Schlutter*'s Account *, Dr. *Wright*, an eminent Phyſician, and two other Gentlemen, well verſed in the Art of Chymiſtry, were the firſt Contrivers and Inventors of the Smelting Furnaces now uſed in *Flintſhire*; which were not compleated till the Year 1698, as is expreſly affirmed.

I have by me a Print of thoſe Furnaces, which I have compared with the Furnaces which I have found erected in this Country; but cannot ſee the leaſt Attempt offered towards an Improvement upon the Author's firſt Deſign; except, that there is added another Chimney; which, ſome of our preſent Smelters, look upon as a great one; but, I am far from agreeing with them in that Point, and do believe it to be quite the contrary; and, certain I am, that it is directly oppoſite to the Inventor's firſt and chief Intentions: They are all ſenſible, what a great Quantity of Metal is loſt in their Chimnies, as this has appeared by many Inſtances, but more particularly in a late Experiment, by which there was got out of one Chimney, and that of no long ſtanding, as much Silver as made a Pint Mug. How inconſiderate and miſchievous an Alteration then ſhould that be deemed, inſtead of being called an Improvement, which gives another Paſſage for that to eſcape, which they by all Means ought to confine and preſerve? Was it not, on the contrary, wholly incumbent on them to have ſtudied and contrived how to have ſmelted with leſs Chimnies, or at leaſt to have removed them, as far as poſſible, from the Ore? Of which a ſingular, but indiſputable Inſtance, may be ſeen in the Structure and Management of Glaſs-houſe Fires.

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* Mr. *Schlutter*'s full Inſtructions for Smelting-works, publiſh'd in the *German* Language, P. 116.

It muſt be acknowledged, that the ſmelting in Furnaces here, is a very ingenious Contrivance; and the Inventors had certainly a true Knowledge of Smelting-Furnaces; becauſe they were well acquainted, that, in foreign Parts, where hard Ore is the chief Product, they laid under an undiſpenſable Neceſſity to erect their Furnaces and Smelting-works on Rivulets, ſo as to make the beſt of the Slacks produced in ſmelting their Ores: But the Ore produced in this Country being of a ſoft Nature, they wiſely conſidered, that it did not neceſſarily require ſtamping the Slacks, but that the Metal might be ſmelted out without making uſe of that Method; and that it was more convenient and beneficial for the Uſe of this Country to contrive ſuch Furnaces as might be erected any-where near the Mines: Since they were erected, the Smelters in *Norway*, where the Ore is ſoft as it is here, have made great Improvements of them; but, in this Country, no Improvements have been made in the Point the Inventors aimed at; but, on the contrary, have unluckily fruſtrated their whole Intention, by erecting the Smelting-works near Rivulets, and thus acted, in Contradiction to the Foundation of their real Perfection, which in ſo large a Scope was laid down by the Inventors. Upon ſome of them running into this erroneous Notion of erecting their Works for working of Stampers, the other Proprietors, whoſe Works were not on Rivulets, were obliged to make uſe of Men to powder the Slacks, and, by this Means, the Smelters were quite prevented from making any Improvements; for, as Neceſſity is generally the Cauſe of Invention, if the Smelters had been left to deal with the Slacks only by Fire, I do really believe they would have long ſince found out a Method to have gained more Metal than they can by their Slug-ſtampers, and Powdering-works; for this Ore, by reaſon of its Softneſs, in ſmelting the Metal, is diſperſed into the moſt extended Parts of the Slacks; ſo that nothing but our grand Menſtruum, the Fire properly made uſe of, can ſet the metalline Parts at Liberty, and collect them into a Body; and it is in this Menſtruum we muſt look for the Remedy, and not to think to gain it by the Stampers. By the Method uſed in ſtamping the Slacks, the Parts waſhed away are equally metalline to what are left remaining; and, beſides, by their unskilful Manner of Smelting, what Metal does remain, is never effectually obtained.

*Juvat integros accedere fontes,*
*Atque haurire, juvatque novos decerpere flores.*

Is it then not evident, that they ought to have contrived a Method of Smelting without the Aſſiſtance of Water and Wheelworks, or manual Labour, for pounding Slacks, and to have been enabled to work their Ores in ſuch manner, that their Slacks would require no ſtamping; as is effected by the *Norway* Improvements, which has thrown all this Machinery aſide, and was the original Intention of the Inventors; but, had they been as aſſiduous as their Neighbours in this great Affair of Smelting, they would never reſt ſo contented with their tedious, expenſive, I may likewiſe ſay, unprofitable Atchievement; but, having thus got a Method to make ſomething of their Slacks, they are quite careleſs in making any further Inquiry, or bending their Genius towards gaining any further Advantage or Improvement in an Affair which ſo requires it.

Some in *London*, and others here in *Wales*, have endeavoured, by what may be called a mathematical Contrivance, to make an Improvement upon theſe Furnaces, by conveying Water and Air upon them, and ſo, by theſe Inſtruments, forcing and increaſing the Strength of the Fire. In *London*, it was attempted by bringing the Air from the River *Thames* through a Channel under Ground, and arched with Brick, made like a Sewer or Drain to the Bottom of the Furnace; but this did not anſwer the Succeſs intended, for they had the Mortification to ſee, that both Metal and Fire made the quicker *Exit* or Paſſage through the Chimney; and how could it be otherwiſe, for there is not any thing in the Creation, but what will avoid or fly from its Enemies if poſſible? And what can be greater Enemies in Nature, than Air and Water are to Fire and fluxed Metal, when brought in upon them in ſuch a violent Rapidity? One of my Acquaintance, a Man of good Underſtanding in moſt Things, was concerned in this Contrivance; but he could not, by any Means, conceive the Reaſon, why this ſmelting Project miſcarried, which was believed to be brought to its utmoſt Perfection, as the Fire was carried with a clear brilliant Flame ſome Yards above the Chimney; but ſo far was this from coinciding with the chief Intention, that it was really the Cauſe why it proved abortive; becauſe the moiſt watry Air drove the Fire from the Place where it was moſt wanted, leaving only ſuch an one behind as calcined the Lead to Aſhes; thus we ſee, that mathematical Attempts are ſometimes founded on a wrong Baſis, and that they ſhould ever be backed by Experience; and that oftentimes, eſpecially in theſe Caſes, the plain and ſimple Reaſoning of Metallurgy, is preferable to theſe aſpiring Ideas.

I think it is neceſſary to mention a Word further concerning theſe two great Enemies in Metallurgy, Air and Water when not properly adapted; Water muſt be intirely avoided, except it be in waſhing, imbibing, and for receiving Quick-ſilver, when extracted from its Ore. Air, on all Occaſions, muſt be ſparingly uſed; the Fire indeed will not burn without it, but then it muſt not be ſuffer'd to play upon the Metal; this I am convinced might be done, and the Air, as an Agent uſed, without permitting it to rob us of the leaſt Particle of Metal; were we but to erect ſuch Places to ſmelt it in, as they who ſmelt the Glaſs Metal for making Glaſs, or in like Manner as a luted Crucible is placed in the Fire, where the Force of the Fire acts thro' the Crucible, and fuſes the Metal, without expoſing it to the Air, or ſuffering the Fire immediately to act upon it, contrary to the Smelting-Furnaces now in uſe. This Practice is intirely avoided by the Glaſs-Makers; for, was their Glaſs-Mixture called by them Glaſs-Metal, nakedly expoſed to the Air, and the Fire permitted to exert its Force upon it; and had they the like Chimnies as are uſed in the Lead-Ore Furnaces, the Mixture of the Glaſs-Metal would be deſtroy'd by the Exhalation of its moſt eſſential Particles, which ought to be taken into due Conſideration by the Lead-Smelters in this Country. I have heard of an Attempt to retain the Metalline Particles, which are exhaled, by a Reſervoir of Water, placed in ſome Part of the Chimney; but as this is not attempted with any Succeſs, I ſhall not animadvert upon it; but will proceed to point out, in Particular, what a Smelter ought to know before he takes upon him to direct a Smelting Work.

A Smelter, in the firſt Place, ought to be an exact Aſſay Maſter; that is, he muſt be a perfect Artiſt in trying Ores and Minerals in ſmall Parcels, in order to come to a Knowledge of the reſpective Metals they contain, in reſpect both to their Quantity and Quality. This, by ſome of the Learned, has been called *Ars Docimaſtica*, or the Art of Trying and Aſſaying; he muſt alſo get acquainted with the exact Nature of the Salts and Fluxes, and what Power they have upon Minerals, and carefully avoid intermeddling with the ſecret Myſteries, as occult Properties of any one or other of the Ingredients he makes uſe of; otherwiſe he will confuſe his Ideas, and plunge himſelf into a Labyrinth of Darkneſs, out of which he may never afterwards be able to extricate himſelf. It is greatly to be lamented, that ſo many Books, for Ages, have been uſher'd into the World, under the Pretence of teaching the Art of aſſaying Metals, which have greatly contributed to caſt a Cloud over the Science, and much more obſcure it, than promote it; and often has rais'd freſh Doubts, inſtead of clearing up the old ones; and render'd it more abſtruſe, rather than more clear and certain. This, and not without Reaſon, has deter'd ſome promiſing Genius's of this Country from entering upon the Study of this Science, who otherwiſe might have made a conſiderable Progreſs therein. *Erckern's* Treatiſe on this Art, is one of the beſt of former Times; but it is ſo badly Tranſlated by Sir *John Pettus*, that there is ſcarcely one Proceſs in it without a very material Error; but Dr. *Stahl* has prodigiouſly advanced it, and reſtored us from Darkneſs to Light; but this Nation is yet at a great Loſs for want of a good Tranſlation of the Works of that moſt excellent Metallurgiſt, none of them having been yet attempted, except his Chymical Lectures, which have been render'd into *Engliſh* by the eminently learn'd Dr. *Shaw*; but theſe are too conciſe, and only the Heads of what he uſed to explain to his Pupils; ſo that it is abſolutely neceſſary to tranſlate the others, which are publiſh'd in the *German* Language, to render them compleat. Dr. *Cramer*, who followed *Stahl*'s Principles in his Docimaſtical Art, is render'd into *Engliſh*; but that has the ſame Defect, and is as much too conciſe as the other, ſo can only ſerve as a Memorandum Book to a Maſter; but a Beginner, who is not well acquainted with the Principles and Rudiments of this Science, I apprehend, can reap very little Benefit from it.

It is requiſite, that a Smelter ſhould be a competent Judge of *Fire*, that he ſhould be acquainted with its wonderful and prodigious Force and Power; for, if he underſtands not its different Degrees of Action, it will be impoſſible for him to make a right Aſſay, or bring any Thing to Perfection in Metallurgy. A conſiderable Number of Inſtances have fallen within my Obſervation ſince my coming hither; many have aſſay'd Metals under my Direction, who, when I was preſent, always ſucceeded; but, when they attempted it without me, and managed the Fire themſelves, they always failed, at leaſt their Proceſs never anſwered their Expectation; whereas had they had a true Notion of the different Degrees of Fire, and thoroughly underſtood its Force of Action, they would undoubtedly have ſucceeded. No one, in Juſtice, can preſume to undertake the Management of a Smelting-work, who is not well acquainted with the chief Agent, ſince, upon it, the whole Art depends.

2*dly*, What we read in Books concerning the different *Degrees* of *Fire*, is of ſome Uſe to the young Smelter, as a Body of Muſick is to the initiated Muſician; neither can the one, nor the other, be aſcertain'd but by Experience; a patient, and conſtant Practice, is abſolutely requiſite. Give me therefore leave to adviſe all commencing Students in Metallurgy, not to rely upon imaginary Theory or Conjecture, nor to believe any Thing but what has been confirm'd by his own Hand Labour; for it requires the Employment and Satisfaction of all the Senſes, to judge rightly of it.

3*dly*, A Smelter muſt be acquainted with the Nature of *Clays*, and endeavour as much as poſſible, from Time to Time, to improve his *Fire-Bricks:* The Knowledge of this is attain'd by judging and experiencing the beſt and exacteſt Proportions of the Ingredients proper to be mix'd for making the Bricks, and the niceſt and compleateſt Method of burning them; from hence great Advantages may be reaped; it is a Thing therefore by no Means to be neglected: To this Claſs alſo belongs the Knowledge of Bone and vegetable Aſhes for making Teſts; theſe are all to be well burnt and prepared, their Salts to be totally extracted, and the Teſts well form'd with them, and all other Concomitants and Dependencies duly weighed and regarded.

*4thly*, He muſt be well skilled in the *Architecture* of *Furnaces*, with the Manner of erecting them: The Knowledge of one or two only will not be ſufficient; he ſhould underſtand all the different Sorts; becauſe ſome Ore works much better in one kind of Furnace than another; ſo that he ought to make himſelf acquainted with all, that have been uſed in different Ages, as well as different Nations: He muſt alſo be ever aſſiduous in trying Ores and mineral Mixtures in ſmall Furnaces; this will give him an Underſtanding of which are moſt fit for his Purpoſe, and make him ſenſible of the *Force* of *Fire*; hence he will be enabled to frame his Furnaces in ſuch a Manner as to ſave a great deal of Fuel, for Fire is ever obedient to the Artiſt.

*5thly*, He muſt be acquainted with every other *particular* and *manual Operation* in the ſmelting Buſineſs, that he may be able to direct every Branch of it; for nothing can be more evident, than that he is the greateſt General, that knows and is experimentally acquainted with the Duty of every Individual that is ſubject to his Command, from the meaneſt Centinel, to the higheſt Officer.

*6thly*, A *Smelter* muſt, by the Helps of *Metallurgy*, and *chymical Analyſis*, arrive to a Knowledge of the inward Texture of *Marcaſites*, *Mondye*, and ſuch like Minerals, which in theſe Parts are called Sulphurs; he will find, that, by mixing them with Lead Ores, they will frequently produce noble Metals, which they will yield to Advantage; but, when tried by the Fire alone, they will not afford any thing, but will either turn to *Scoriæ*, or evaporate; was it not for this Knowledge and Experience, the Mines in *Germany* would not be ſo conſiderable as they are; for it is oftentimes found, that eight or more of theſe Foſſils, which ſeparately or ſingly would not produce any thing, yet, being diverſely mixed with Lead-Ore, their Produce becomes conſiderable.

This, I am certain, is a large Field for Employment, when I take a View of the many mineral Species, which appear ſo abundantly all over *Wales*, and there remain wholly neglected, under the ignominious and deſpiſed Names of Sulphurs; but, if we would employ ſome Part of our Time to reflect and conſider that they were created by the omniſcient Power for ſome Uſe or other, we ſhould not ſo careleſsly paſs them over, and neglect them. I am inform'd there have been ſome Attempts made in this Kingdom to extract a fuſible malleable Metal, out of Mondye, and other ſuch-like Mineral Subſtances, vulgarly term'd Sulphurs, but they have proved ever unſucceſsful; yet, I am ſatisfied, that theſe Diſappointments aroſe for want of proper Mixtures; and, it is moſt certain, that their Expectations would not have been fruſtrated, had they, inſtead of Lime, ſo commonly made uſe of in Smelting the Lead Ore in this Country, made uſe of the Marcaſites, and other mineral Species in Smelting that Ore, as a little Experience would ſoon make manifeſt: If, from what I have ſaid, any ſhall proceed to make Trials, in order to render theſe Things ſucceſsful, let them be made in ſmall Quantities; and, from the Reſult of ſeveral of them, they will become proper Judges of what is moſt ſuitable; for, it is about theſe ſulphureous Bodies, ſo called, that Part of Metallurgy, which appertains to the Art of mixing, is chiefly concerned; and the Accompliſhment of a Smelter very much depends upon a judicious Skill therein. This is ſufficiently evident from the Effects of mixing *Lapis Calaminaris* with Copper, which, by itſelf, cannot be brought into any metalline State.

Many Inſtances of this Nature might be alledged; but this, I ſuppoſe, will be ſufficient to make you agree with me, that this well known Experiment deſerves the Attention of the moſt diligent and curious Searcher into Metallurgy; becauſe it proves, 1*ſt*, that, by Mixture, a metallic Quality is produced, which could not be obtained from the *Lapis Calaminaris* alone: 2*dly*, By this, it evidently appears, that Metals will take a Tincture; therefore Dr. *Henkel* very juſtly obſerves, how neceſſary it is to try all metalline and mineral Ores by Mixture, according to the moſt common mechanical Operations *.

7*thly*, A Lead Smelter, in particular, muſt always obſerve, that as long as the Metal is in the Furnace, a ſufficient Quantity of Phlogiſton, or inflammable Subſtance, of an oily or greaſy Nature, which contains no acid, is conſtantly to be added to

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* Dr. *Henkel's* leſſer Minerology, publiſhed in the *German* Language, *p.* 65.

it; becauſe Lead, as ſoon as it melts, immediately begins to calcine into Aſhes; but, as ſoon as any Phlogiſton is thrown upon them, they are immediately brought into their priſtine metalline State again. The Truth of this may be made apparent by an eaſy Experiment; take a Piece of Lead, free from Droſs, put it into a clean Crucible, and ſmelt it in a moderate Fire, there will firſt ariſe on the Metal a thin Skin or Cuticle, which ſoon after will turn to Aſhes; throw upon them, while they are ſwimming upon the Metal, ſome Oil, or the Fat of any Animal, and the Aſhes will be inſtantaneouſly reduced into Lead again.

The Phlogiſton made uſe of in large Furnaces, muſt, as has been obſerved, be without Acid; but any Fat, Greaſe, and Wood-charcoal, or Wood-charcoal alone, may be ſubſtituted. This I intend as a Hint for thoſe Smelters, who, following the common Practice of the Country, uſe, for this Purpoſe, ſmall Pit-charcoal, mixed with Lime; but, as I am ſatisfied, that the Acidity in theſe Foſſils muſt be detrimental to the Smelting of the Ore, I would adviſe them to take ſmall Wood-charcoal in their ſtead, particularly as no conſiderable Quantity is required.

8*thly*, It is abſolutely neceſſary that the Smelters ſhould refrain from the Uſe of

Lime in ſmelting of Lead, and find a Succedaneum to it; for, by a ſmall Degree of Fire, the Lead vitrifies, or is turned into Glaſs, when Lime is mixed with its Ore, as has been obſerved a long Time ago, and lately, in particular, by Dr. *Cramer* *: Nor is it poſſible to regain all the Lead when once vitrified, and involved in the Slacks, by that indiſcreet Method, either by the Help of Stampers or Slack-hearths, which is the Reaſon that the Roads are ſo much mended with them, having the very Appearance of Glaſs itſelf.

I never yet could get any ſatisfactory Account, why they made uſe of Lime in Smelting; if it is intended to abſorb the Sulphur and Arſenic, there are other Things as cheap, as ready, and much more beneficial for the Purpoſe; theſe Aids and Abſorbents, I apprehend, ſhould be looked for in Iron, Iron Ore, Magneſia uſed in Glaſs-making, Horn, Stone, and other Things of this Kind; it therefore behoves every one to examine and try which is moſt agreeable to the Ore, whether Part, or all of theſe Articles, as it may ſometimes happen, are required. I am ſure, if any one will make the Experiment, as I have before directed, according to the Rationalia of Metallurgy,

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* Dr. *Cramer*'s Elements of the Art of aſſaying Metals, *p.* 17. and 134.

tallurgy, his Labour will be very well rewarded with Profit.

*9thly*, The Smelters of this Country ought to have a perfect Knowledge of Precipitation; which, that they may have an Idea of, I will point out a Method to precipitate the noble Metals out of Lead, which ought to be followed, inſtead of their preſent Way of Cuppelling; and is as follows: When the Lead is ſmelted out of its Ore, it muſt be let out, and run into large Iron Ingots of a conic Figure, each containing about three or four hundred Weight, but no more; their Inſide muſt be firſt rubbed with Fat, about two Minutes before the fuſed Metal is let into them; but the Matter which is to precipitate the noble Metal from the Lead, is to be mixed with it whilſt flowing in the Furnace, before it is runned, or poured off; when in the Ingot, the Outſides of it muſt be beat with large Mallets, or wooden Hammers, in order to give it a Motion, till the Metal becomes hard and fixed; which being cold, and then beat out of the Ingot, the noble Metal will be found in a Regulus in the conic Part of the Ingot, ſeparated from the Lead by a ſmall Cuticle; but as the noble Metal in the Regulus is never pure, it muſt be refined, *S. A.* as Occaſion requires.

The Materials for this Precipitate muſt be looked for amongſt the Marcaſites, Semi-Metals, and Iron; obſerving, that ſuch muſt be choſen as will not mix with the Lead, otherwiſe it will be rendered unfit for mechanical Uſe.

I muſt take notice of a Copper Ore which is frequently found, called in *Germany* Copper-Hog, from its Oppoſition to Fuſibility: This, for many Ages, baffled the Efforts of the moſt noble Metallurgiſts, who could by no Means fall upon a Method of ſmelting it, although it was rich in Copper. I find Dr. *Cramer* has ſlightly taken notice of it under the Name of *Vitrean Ore* *; but I ſhall mention the Way, by which this Ore came to be ſmelted, for the Inſtruction of the curious Metallurgiſt of this Country, who, it is likely, is quite a Stranger to it; for all remained in the Dark, till the moſt learned Dr. *Zimmerman*, of *Friburg*, gave us an inſight into its abſtruſe Nature, and made the Diſcovery in the following manner. This curious Gentleman, as he was taking a Walk near a River's Side, ſearching into the Productions of Nature, he found a Piece of Iron, the Crocus, or Ruſt, of which, had attracted ſome of the Sand, and rendered it into a hard and ſtony Con-

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* Dr. *Cramer*'s Elements of the Art of Aſſaying Metals, *p.* 145.

crete; all his Attempts to fuſe it, even with the ſtrongeſt Fires, were in vain; theſe Defeats turn'd his Thoughts another Way, reſolving, if poſſible, to find out the Contents of this Concrete; therefore, to effect it, he made a Paſte with Water, of three Parts of Sand, and one Part of Iron-filings, put it into a Glaſs, and wetted it with Water at different Times; by which Means, in leſs than ſix Months, the Mixture was turned into a hard ſtony Concrete, without any other Aſſiſtant; and this, like the former, could not be fuſed by Fire: By this Experiment he drew his *Rationale*, and became acquainted with the Nature of the *Copper-Hog*, or *Vitrean Ore*, and found out the Cauſe of the Difficulty he had met with in fuſing it; neither could he well be any longer ignorant that this was the Caſe, that its opponent Parts, beſides its proper copper Baſis, were an Iron Earth, intermingled with Grit and Sand; which, whilſt united to it, cauſed its Reſiſtance to Fluxion, but, when once ſeparated, according to the Rules indicated by theſe Opponents, that is, by a peculiar Method of waſhing, it may be worked to Advantage.

The ſame as is related of *Copper Ore*, does frequently happen to that of *Iron*, as Diſcoveries have made manifeſt; therefore the Iron Smelter muſt be very careful to free his Stone from all Sand or Grit, before he attempts to ſmelt it, otherwiſe he will find his Labour too frequently unſucceſsful.

What has been here related of the Concomitants of Copper and Iron Ore, frequently attend that of *Tin*; for which Reaſons the Smelters ſhould mind not to roaſt ſuch Ore too long, otherwiſe a great Part of the Metal will be loſt by its being formed or turned with the Iron Earth, into ſuch like ſtrong Concretes or Scoriæ which the Fire cannot maſter, ſo that it ought to be ſeparated by waſhing, as before noticed; and this is more eſpecially to be regarded, as Tin is ſeldom found without them.

*Lead Ore* is not always exempt from theſe Impediments, and the worſt Steel Ore, which yields no Silver, is the moſt liable to them; I therefore judge it to be very neceſſary, that the Smelters ſhould make themſelves acquainted with theſe natural impeding Cauſes attending Ores, and the Means to rectify them; for which there is the more Reaſon, becauſe from the Symptoms which now appear to me, I apprehend it will not be long before they meet with ſuch Kind of Ores in their Mines.

10*thly*, Since I have entered upon a Detail of theſe abſtruſe Ores and Minerals, I cannot help putting the Smelters in Mind of a Sort of Lead Ore, which is yet unknown to them in *Wales*, and with which they ought to be acquainted: It is a kind of red Lead Ore. appears of a red clay-like Subſtance, and feels ſomewhat ſoapy *. I have very great Reaſon to believe, that ſome Hills in *North Wales*, contain large Quantities of it; which, conſidering the preſent State of Mining, as well as for many other Reaſons, I judge it may be looked after, and uſhered into ſmelting, that there may be Employment for many Furnaces which now lie unemployed, and going to Ruin.

11*thly*, To be thoroughly well verſed in mineral Manufactures, is one of the greateſt Accompliſhments of a Smelter; becauſe there come many Things in his way which will turn out greatly to the Advantage both of the Country and Proprietors; but as yet there is no notice taken of them in theſe Parts, for want of knowing what uſe to put them to, they are here trod under Foot, and looked upon as Rubbiſh, and lie utterly neglected; for this Reaſon I ſhall point out ſome few Inſtances of this Kind. 1*ſt*. The Flowers that adhere to and ſettle in the Chimnies of the Furnaces, may be wrought to conſiderable Advantage,

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* Dr. *Cramer*'s Elements of the Art of Aſſaying of Metals, *p*. 148.

tage, by making them into Spelter or Zink; and I know, by Experience, that the Spelter which might be made of theſe Flowers, or out of the Lead Ore, and *Lapis Calaminaris*, is equal in Goodneſs to that which is brought from the *Eaſt Indies*, and much ſuperior to that which comes from *Germany*; becauſe the *Germans* do not ſuffer theſe Flowers to rob them of ſo much Silver as they do here, and the Lead Ore which they uſe with the *Lapis Calaminaris*, is very poor in Silver; and Silver, being one of the beſt component Parts, or richeſt Ingredient of Spelter, in regard of the great uſe there is made of it in ſodering the noble, as well as other Metals, that muſt certainly be the beſt, which has moſt Silver in its Compoſition. Another Inſtance is making Vitriol; for which Purpoſe abundance of Foſſils lie ſcattered here and there, as I have mentioned, in many Places of *Wales*, and are frequently buried among the Rubbiſh of the Mines, where they remain intirely neglected; yet, if in the Poſſeſſion of inquiſitive and induſtrious People, would be manufactured into white Vitriol to no ſmall Advantage. *Cobolt* again would furniſh us with Stone-blue, and is found almoſt in all Lead Mines; but Things of this Nature are ſo numerous in this Country, that it would be too tedious to mention them here.

12*thly*, I will point out a Method, by which the ſkilful Metallurgiſts treat ſuch Minerals that will not yield any Metal by the common Way of Fuſion; it is, what may not improperly be called, maturating the Mineral by the Help of certain Liquids, as by Lixiviums, or Lies made of Salts, Lime, and ſuch other Ingredients as will diſſolve in common Water. In theſe the Minerals are to be imbibed, being firſt made red hot, and then thrown into them, which is to be ſo long continued and repeated, till it is thought fit for fuſion; but if the Mineral be of ſuch a Nature that it cannot bear the Fire without deſtroying its Texture, on account of its volatile Contents, then it muſt be reduced to Powder, put into a Cloth, and the Liquor poured boiling hot upon it, and ſuffered to percolate or ſtrain through it, which muſt alſo be repeated ſo often as is neceſſary for its proper fuſion: By theſe Means, conſiderable Quantities of noble and ignoble Metals have been obtained from Minerals, which otherwiſe would not produce any thing. But, before we proceed to treat Minerals in this Manner, we ſhould be ſenſible what heterogeneous Matter it is that they partake of, which prevents their fuſion in a common Way; as for Example, if Acid and Sulphur abound, we have recourſe to Alkalies, which correct and abſorb the Acid, and diſſolve the Sulphur; if Bitumen, or Earth-pitch, clog the Mineral, then Lie made of Lime, or elſe common Water and Air, muſt be our Menſtruums to diſſolve them; if either of theſe laſt Methods is made uſe of, it muſt be a Work of Time, becauſe the Lime-lie or Water is to be poured upon it at ſeveral Intervals, and in the intermediate Space it is to be expoſed to the Air, and that as often as Occaſion ſhall require. By theſe Means, and with the Aſſiſtance of proper Machines, Minerals may be worked in large Quantities at once; ſo that the Smelter ſhould not deſpiſe theſe as tedious and unprofitable Diſcoveries.

The laſt Method I have mentioned, has indeed by ſome been cenſured, by others derided, and looked upon as quite uſeleſs in Metallurgy, judging ſuch Proceſſes of no Service in the Treatment of ſtubborn, adverſe, and hard-flowing Minerals; but, in anſwer to ſuch Perſons, I need only appeal to Experience, the very Touch-ſtone whereby all Matters of this Nature are to be decided, and their miſtaken Notions will clearly appear from the Proceſs made of Silver and Quick-lime; which is as follows: Take Lime hot out of the Kiln (it muſt be the hard Stone-lime) pour Water directly upon it, and make it thus into a ſtrong Lie, ſmelt pure Silver, that has not any Gold in it, and throw it into the Lie as ſoon as it fluxes; having repeated this four or five Times, the Silver will, upon Trial, be found to contain ſome Gold in it, which by this Means is really conſtituted; ſuch therefore as will deny the above-mentioned Maturation of Metals, let them try this Experiment, and aſſign the Reaſons how this Gold came into the Silver; to me, it is more convincing, than all their ſeeming Force of Argument, and Beauty of Language: Perhaps it may be ſaid, that the Gold was occaſioned by often ſmelting the Silver in the Fire; but this cannot, by ſound Reaſon or Experience, be any-ways proved; for, I do affirm, that Silver never receives or obtains any Gold by ſmelting, let it be ever ſo often repeated; notwithſtanding what has been aſſerted by *Homberg*, *Henkel*, and other Writers, to the contrary: And ſuch as imagine them to be in the right, I muſt alſo refer to try the Experiment; which will evidently convince them, that no Gold can be obtained from pure Silver by oftentimes ſmelting. And although, I cannot ſay, the above Experiment of Silver and Quick-lime is profitable, or that it can be recommended in a lucrative View, yet it is a curious one, and does moſt manifeſtly demonſtrate the Truth in Queſtion.

By what is advanced, Sir, you may perceive what Knowledge and Induſtry are requiſite to conſtitute a good Smelter; I muſt ſubjoin an unwearied Patience, and a Steadineſs of Mind in his Purſuits; and other neceſſary Ingredients might be added, as a ſound deliberate Judgment, avoiding to draw haſty Concluſions from Experiments, and too much Credulity in Theory: let this therefore be ſufficient for the preſent, for he that is Maſter of what I have aſſign'd, will not want a good Foundation, whereon he may improve himſelf farther; nor is it to be queſtioned, but that he will make a conſiderable Progreſs in this moſt uſeful Science; but as I have mentioned Judgment, give me leave, before I make an End, to ſay a Word or two more relating to it.

A Smelter ought to be extremely exact and nice in his Judgment, that is, as I have mentioned on one hand, neither too raſh or too credulous, nor on the other, too opiniated; becauſe, oftentimes, very great Diſcoveries have been made by illiterate People; ſo it muſt likewiſe be next to Madneſs, to ſcorn and ſlight an half roaſted Alchymiſt, when he tells you ſtrange Things, that at firſt Sight ſurpaſs your Underſtanding; as that he can ſmelt a Diamond *; or that he knows how to manage the moſt abſtruſe ſulphureous or volatile Foſſils; for moſt of theſe People are prodigiouſly well acquainted with Minerals, and have attain'd to be very great Maſters of Fire; to theſe we are indebted for almoſt all the great Diſcoveries and Improvements that have been made in Metallurgy; not that I would have any one give credit to what they offer concerning the Philoſopher's Stone, nor with an implicit Faith to aſſent to every Thing, which they, or any one elſe, ſhall think proper to advance; but with a civil Deportment we may give Attention to what they relate, and weigh diligently what they aſſert, hear their Rationalia of Things, and gain as great an Inſight as poſſible into the various Effects of Fire, and the Art of obtaining and refining Metals, which I promiſe you, will not be inconſiderable. I have generally found theſe Gentlemen, the Alchymiſts, very touchy, and more capricious than the reſt of Mankind; it is this Deformity of Mind, which makes them ſo remarkably diſtinguiſh'd for their obſtinacy; but whether that ariſes from the Cauſes aſſign'd by that celebrated Poet, *Ben Johnſon*, † I will not determine. However, a complaiſant Behaviour,

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* Three Parts of Alkaline Salt, will ſmelt one Part of Diamond into Glaſs.

† *Ben Johnſon*'s Comedy, the Alchemiſt, Act. III. Scene I.

haviour, frequently renders them communicative: What makes me give the above Caution, and take ſo much Notice of their peculiar Genius, ariſes not only from my own Experience of its Conſequence, but alſo from the following unfortunate Event. Our great *Kunkel*, when he reſided at *Dreſden*, was viſited by an Alchemiſt in a very mean and ſhabby Dreſs; for ſuch was this Man's Infatuation or turn of Mind, that he would rather live without Meat or Cloaths, than want Coals: He offer'd *Kunkel* to diſcloſe to him a Secret of great Conſequence; which was, to diſſolve Gold with Alkalies; but *Kunkel* being alſo of an haſty Diſpoſition, poſitively contradicted him, and inſiſted upon the Impoſſibility of it, without ever duly examining into the Affair, or offering to attempt a Trial; this Treatment highly affronted the Alchemiſt, who parted with him quite enraged; ſo that this Secret, though of the greateſt Advantage in Metallurgy, was loſt and buried in Oblivion, by the Obſtinacy and Spirit of Contradiction, which reign'd on both Sides; yet, it has ſince appear'd, that this Aſſertion of the Alchemiſt ought to have been credited, by what has been diſcovered by Dr. *Stahl*, relating to Things of this Nature. I muſt here again caution the young Smelter not to be too credulous in reſpect to theſe Gentlemen, nor even give credit to their Experiments, without very good and ſufficient Grounds; for it is impoſſible to enumerate the Perſons who have ſuffer'd by their Legerdemain Tricks, which they can deviſe with that exquiſite Art and Cunning, that it requires the moſt ſkilful and diſcerning Eye to detect them; many of their deceitful Experiments I am acquainted with, but do not chuſe to divulge them; becauſe, as they are not generally known, it might tempt ſome deſigning Heads to make uſe of them to deceive the Unguarded and Unexperienced.

You require, indeed, an immediate Remedy of me for the Recovery of the now decaying Science of Smelting in this Country; I heartily wiſh I could as readily and effectually do it, as you deſire; but when I conſider how imperfect every Thing relating to it is in this Country, the Reſtorative I fear is not ſo ready at hand; I am rather inclin'd to think my beſt Advice and ſtrongeſt Efforts will prove but like a patch'd Piece of Work; however, when I conſider from what ſmall Beginnings Things oftentimes take their Riſe, and how by Degrees they come to be improv'd, I gain freſh Reſolution, and am ſpirited up to undertake the Taſk, and to give you my Opinion by what Means I judge beſt and moſt convenient to puſh the deſired Attempt forward. It were to be wiſh'd that ſome ingenious Youths were rationally trained up in this Science; but, as this can only be of Service to Poſterity, a Remedy muſt be ſought for to ſerve the preſent Exigencies; and it is altogether unjuſt to deprive them of a Maintenance who have been engaged the beſt Part of their Time in that Buſineſs; and I think nothing can be more equitable in the preſent Caſe, than to point out and endeavour to advance ſuch Methods as will retain them in their Element, which will be much more beneficial to the Nation in general, and to the Proprietors in particular.

As nothing engages Men more in the Purſuit of Things than lucrative Views, I think the Proprietors would find their Deſigns much better anſwered, were they to offer their Smelters a proportionate Reward to every new Diſcovery, which from time to time they ſhould happen to make for the Improvement of the Work; but as this cannot be expected without proper Means to effect it, they are under a Neceſſity of erecting ſmall Laboratories near their Works, wherein Aſſays of Minerals in ſmall Quantities may be made, in order to promote and advance ſuch Diſcoveries; and which, with proper Management, might be done at a ſmall Expence; but as they will work very much in the Dark, unleſs they are acquainted with the Rationalia of the Subject they are engaged in; I would therefore recommend the Peruſal of the following Books to ſuch as are not thus qualified; *viz.* The laſt Edition of *Boerhaave*'s Chymiſtry, with Dr. *Shaw*'s Notes; Dr. *Stahl*'s Chymiſtry, tranſlated by Dr. *Shaw*; and Dr. *Cramer*'s Elements of Aſſaying Metals; and theſe not only to be read and conſidered of, but that alſo they ſhould at the ſame Time make the Experiments, and perform the Proceſſes therein mentioned; for one is not ſufficient without the other to make them comprehend thoſe Works: By theſe co-aiding Means, I am ſatisfied they will be enabled to make ſome Progreſs; and if any Books more advanced in this Science ſhall hereafter be publiſhed, by purſuing the above Method, they will be enabled to underſtand and go through the Proceſſes contained in them. I am,

*SIR,*

*Your obedient Servant,*

DIEDERICK WESSEL LINDEN.

Holywell, *in* Flintſhire,
Oct. 23, 1749.

# LETTER III.

*Shewing by what Means the Arts of Mining and Smelting may be brought into a rational Syſtem; with ſome Obſervations on the Difficulties that will neceſſarily attend it.*

I Thought my two laſt Letters on Mining would have ſatisfied your Curioſity in that Reſpect; but by them, I find it ſtill more and more raiſed, being prompted by a Zeal of promoting the publick Good; now I find you ask me to ſhew you, by what Means a *rational Syſtem* of Mining may be eſtabliſhed? Before, I have hinted, how unwilling I was to deliver my Thoughts on that Subject, for fear of giving Umbrage to many, and for fear that my Time and Labour would be ſpent in vain; but I cannot be ſo ungrateful not to comply with your Requeſt, particularly when I find myſelf ſtirred up to attempt it, by the very ſame Motives that you are to ask it: Who, without Regret, can ſee the Riches of a Country waſted, and its Products neglected? Can any Heart be ſo hardened and inflexible, as to be ſenſible of all this, and yet be ſilent? Methinks I here the Clamour of the Populace crying out aloud for a Reformation! Methinks I hear the Country, as a Duty I owe her, demanding it of me?

Methinks I ſee a Number of Labourers, whoſe Hands want Work, and where Mouths want Bread, requeſting it of me! Do not I hear the Proprietors complain, how their Lands are mangled, how confuſedly, and how unprofitably, their Works are carried on? Can it be otherwiſe, when few there are in this Country that underſtand the Rationale, I might ſay, Rudiments of their Profeſſion? I muſt confeſs, that the Number is ſmall, few at leaſt I have had the Happineſs to meet with, that are acquainted with it; but this a Stranger ſcarce ever durſt to mention, much leſs attempt to maintain; Ignorance has got the Prevalence of Truth; Vanity, and preſumptuous Boaſting, the upper hand of Reaſoning; and the *Empiric* gains Eſteem ſo far beyond the *Rationaliſt*, that it requires the greateſt Patience that Man can profeſs, to bear up againſt the Uſage that one commonly meets with on this Occaſion. However, I will proceed to point out the Way by which the *Art* of *Mining* and *Smelting* may be reduced into a *rational Syſtem*.

A Science muſt be founded upon clear, certain, and ſelf-evident Principles; the very Eſſence or Being of it, conſiſts in a regular, clear, and comprehenſive Order, and Series of Truths and Facts: It muſt be founded upon a Series of Conſequences, deduced from undeniable *Data*; theſe Conſequences muſt in courſe produce others to be connected, and the latter always the Reſult of the preceding or former; but if the *Data*, or at leaſt what is laid down for them, ſhould be falſe, or the Conſequences not regularly and rightly drawn, and ſufficiently ſupported, what ſhould be a Science, will be only a Chaos of Confuſion, and a Heap of Uncertainty. Indeed the Empiric and Impoſtor may ſhelter his Ignorance under ſome Shadow or Appearance of Reaſoning, but then it is only a mere Shadow; his Theory, upon Examination, will be found to be imaginary, his Maxims ill-grounded, and his Practice chimerical and abſurd; he will be found to be wavering in his very fundamental Principles, if he has ever been at the Trouble to lay down any, and to execute the Office of his Profeſſion without either Rule or Order, in an irregular, uncertain Manner; poking out his Road like a blind Man, which, I have too much Reaſon to fear, is the unhappy Caſe of the preſent State of Mining and Smelting in this Part of the Kingdom; but, in this Way, they are too much encouraged and countenanced by ſome of our modern ſuperficial Wits and Pretenders to natural Philoſophy; who, inſtead of having any rational Syſtem, argue in a Vague, unconnected, and inconſiſtent Manner; and endeavour to enſlave, or force their Opinions, with a certain Air of Authority, and ſome Elocution, upon the reſt of Mankind: Hence proceeds the Difficulty of eſtabliſhing a ſolid Theory, and juſt Practice; hence it is, that no advantageous *Scholia* are drawn from their Experiments; for what they daily put in Execution, they know not the Reaſon why it ſhould be ſo; but the irrational are continually oppoſing the Introduction of a regular Science, well knowing, what fatal Effects ſuch an Introduction would produce to their Schemes; though, without ſuch a Support, all that they aſſert upon a Trial, or in what by Experience they have found to ſucceed, whether what they do happens right or wrong, turns out profitable or unprofitable, they cannot account for; all that they can ſay in either Caſe amounts in effect to no more, than that it has happened ſo: But ſuch is the Infatuation of ſome Men's Minds, and ſo ſlender their Application to Knowledge of this Art, that they ſeem, by theſe unſound Proceedings, to be lulled as it were aſleep; but if the Rules, whoſe certainty our Science can ſo juſtly boaſt of, were once known, and brought into a regular ſcientifical Order, the Spirit of Empiriſm, which now reigns, would undoubtedly be thrown off and rejected by the Proprietors; then would they be awakened out of their Lethargy;

thargy; then would they demand a regular Practice; then would they inſiſt upon ſuch rational Proceedings as this Science can clearly evince it is capable of pointing out: It was for this Reaſon that I was ſo ſanguine in my Letter wrote to Mr. *Hooſon* on this Subject; it was he, and others at that Time, who provoked me to uſe ſuch auſtere Expreſſions; for, by denying and rejecting the moſt eſſential Truths, he tended rather to oppoſe this Science then improve it: This the Searcher of all Hearts knows was the Cauſe that forced them from me; therefore I can but think myſelf ill-uſed by ſome, who, I have heard, have put other falſe Conſtructions upon them.

The Impoſtor can ſhelter himſelf no otherways than under ſome ſcattered Truths of this Science; he ſcarcely preſumes or attempts to diſcover any other Knowledge that he is poſſeſſed of; he rarely offers to utter any of its Fundamentals; and, when he does pretend to have any Acquaintance with them, he gives at moſt but ſome bare Hints, and meddles with nothing but its Out-lines; yet, with this precarious Knowledge, helped off with ſome plauſible Elocution, and fair Promiſes of Advantage, does he prevail among the unwary and unacquainted: With theſe Pretences does he inſinuate himſelf into the Favour and good Graces of the Credulous and Avaritious;

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by theſe he too often makes it appear to them, that he is a real Maſter of the practical Part of this Science; nor can he be well detected; for as he advances no regular Hypotheſis, he keeps himſelf clear from all Scrutiny; he cannot be examined by any Rules of Art, as in other Sciences, ſo the whole Proof muſt be left to the Event; but ſuch are the Diſpoſitions of ſome Men, that Hopes of Gain, gilded over in this ſlight Manner, ſpirit them on to launch out into Works, without due Conſideration, or proper Inquiry, whether they are likely to turn out to Advantage, or otherwiſe; it is by this Means that innumerable Impoſitions have been carried on; hence it is, that ſo many Works have miſcarried, which otherwiſe would have remained in *ſtatu quo*, till ſome more judicious, and better qualified Perſon, had been raiſed up, who would perhaps have worked them to Profit.

Had a juſt regard been had to proper Inquiries, and the Affair in Hand been duly weighed and conſidered, all theſe Abuſes would have been prevented, proper Means would have been thought of, ſuch Perſons would have been looked for and encouraged, who were truly and thoroughly well verſed in this Science; and by them, in this Time, it would have been properly regulated, and in a State of Improvement; as would be evident, were but the known and unerring Laws of the Art once reduced into a ſyſtematical Order; which in this might be as regularly done as in any other Science whatſoever; particularly as I know of none, in which greater Lights have been obtained, than in this: In regard to what I have here advanced concerning this Science, and towards framing its Principles into a Syſtem, I would not here be thought to mean a *ſpeculative hypothetical* Theory; but ſuch an one as is founded upon invariable and undoubted *Axioms*, which are capable of being ranged and placed in an exact Order, and ſo methodized, that one thing ſhall be the neceſſary Reſult of another; the whole evidently and manifeſtly eſtabliſhed and conducted by Experiments, and laid down and explained in ſuch a clear Manner, that it may be comprehended by any common good natural Capacity; for it ought to be adapted to the Literature of the *Miner* and *Smelter*; and, if this is not done, it is to be apprehended, that all other Attempts will be rendered abortive, and the Art remain as diſtant, and as far elongated from Perfection, as it is at this Inſtant.

It may, perhaps, be inferred, from what I here propoſe, that I would have every Miner and Smelter compleat in the Knowledge of every thing I have laid down, before I look upon him capable of having any Employment in theſe Affairs; but my Intention is not to delineate ſuch a Method as will burthen him in that unreaſonable Manner: You will eaſily obſerve, Sir, that I am for exploding from hence all deep ſpeculative Learning; that I am for deducing it into a clear, plain, and intelligible Syſtem; that I am for preventing it being too prolix, by baniſhing all uſeleſs and uncertain *Hypotheſes*; ſo that it need not be queſtioned, but that any Man may become Maſter of it in a reaſonable Time: To facilitate the Comprehenſions of it, I would have this Science to be ranged under divers Heads, and divided into different Branches; all which I have already ſpecified and expreſſed in as full and large a Manner as I could, for the Benefit of thoſe that will attempt to attain to the Knowledge of it: And this, I dare venture to ſay, that whoſoever does courageouſly and perſeveringly engage in the Study of this Science, will find, that all the imaginary Difficulties are ſo far from being unconquerable, that, on the contrary, he will be engaged in an eaſy, delightful Study, as well as a moſt profitable Undertaking.

There is not any Method that appears ſo conducive towards effectually carrying on Works of Mining and Smelting, as that which is eſtabliſhed in *Sweden*; there the whole Buſineſs is under the Direction and

Management of Commiſſioners, in the ſame Manner as there is in this Kingdom a Board of Trade and Plantations; there the principal Branches are under the niceſt Rules, and exacteſt Regulations imaginable: They have two Perſons who are principally employed, and under whoſe Direction are put all the Machine-works belonging to their Mines; theſe again have Mechanicks under them, who are very induſtrious, and continually aiming at ſome Improvements; then, in order to promote Diſcoveries, they appoint People in every Province and County, who are called Minior Metal Searchers; becauſe their daily Employment, and conſtant Buſineſs, is to ſurvey the Grounds, and examine the Mountains, for all Kind of metalline Ores, Minerals, Veins, Beds, *&c.* Whatever Diſcoveries happen to be made by theſe, they are inſtantly reported to the Board; to which, if they ſeem likely to prove beneficial, Orders are iſſued out immediately, and Miners are ſet to work in the moſt advantageous Manner; after the ſame Method are all the other Branches of this Science carried on, in which the ſame Spirit prevails: How far any thing of this Kind can be attempted and put in Execution, or what Perſon in Power will eſpouſe and patronize ſuch an Undertaking, I muſt confeſs I am yet altogether at a Loſs to know; but, certain I am, that nothing can contribute more to aggrandize this State and Kingdom, than a due Encouragement of ſuch an Undertaking, and a ſtrict Promotion of it, as far as the Extent of the Thing will admit.

In order to facilitate and accompliſh the Perfection of this Science, and to range its Laws in ſuch a juſt Order, ſo as to render the Whole into a compleat Body of Mining and Smelting, I look upon the following Method moſt proper to be purſued.

In the *firſt Place*, both *Mining* and *Smelting* ſhould be treated in an *hiſtorical* Manner; a juſt Account of them ſhould be brought down from the earlieſt Ages to this preſent Time; in which particular Notice ſhould be taken, what Improvements have been made, and what Declenſions and Decays it has ſuffered, and in what Ages, and in what Nations, they have happened.

2*dly*, A true Theory muſt be *eſtabliſhed*; the *Symptoms*, which by Experience have been confirmed to be indicting, whether good or bad, muſt be laid down in their proper Order; the Rationale of them muſt be given; thoſe that are *equivocal* or doubtful, muſt be ranged under one Claſs, and thoſe that are univocal or *Pathognomonick* under another; here it muſt be ſhewn, how they are dependant upon each other, or how one is the neceſſary conſequent of the other; taking care, that the Whole be demonſtrated in ſuch a plain and eaſy Manner, that it may juſtly be ſaid to be adapted to the meaneſt Capacity, though founded upon an exact *Syſtem* of *natural Philoſophy*; ſo that a proper Regard is to be taken, that nothing is aſſerted, but what may, and is made evident from the ſame Principles.

3*dly*, All the Branches of the *mechanical* Part of Mining, or the various Ways of working under Ground, muſt be expreſſed and particularized, and made as clear as poſſible; the different Methods of different Countries muſt be ſet forth; for from every one of them ſomething may be collected towards improving our own; therefore we muſt not forget to mention the *Tools*, which, with all curious under Ground *Structures*, muſt be delineated upon Copper Plates.

4*thly*, Draughts of all *Machines* appertaining to Mine-works, muſt in like manner be exactly exhibited upon Copper Plates: In this Branch we need not be aſhamed to borrow from Foreigners; amongſt thoſe that have been invented by the *Swedes*, we ſhall find a great many worthy of our Obſervation; for, in my Opinion, they have exceeded all I have ever ſeen by other Nations, particularly in one, which, in all Reſpects, anſwers the End in a very ſurpriſing Manner, without the Aſſiſtance of Ropes; as is particularly deſcribed by Mr. *Swedenborg*, in his *Regno Subterraneo.*

5*thly*, As the *mineral Veins* of one Country differ from thoſe of another; for inſtance ſake, I will mention two of the moſt material ones: *Veins* on the Continent are in long Ranges and Rakes; they are not there liable to Bars or Out-cuts; they therefore moſt commonly run pretty ſtreight and certain, for as many Miles as the Courſe of the Mountains will admit of; they are intirely unacquainted with Beds and Bellies in their Mines, which are moſt commonly called Pipe-works: So, on the contrary, in all Iſlands, the Ranges or Rakes are ſeldom found to run in ſtreight Lines; their Veins are very uncertain, ſeldom continue long; they are frequently impeded with Bars or Out-cuts of the Rocks, and the Ore is too often found in Bellies and Pipe-works; in fine, they have ſcarce any thing alike or common with thoſe on the Continent, except the Underſets, which are generally the ſame in moſt Places: The ſame Uncertainty and Irregularity holds good, and extends itſelf even to the very Rocks and Mountains, which, in this Country are different, in different Counties; thoſe in *Flintſhire* are moſt commonly ſoft, thoſe in *Montgomeryſhire* are hard, and thoſe in *Cardiganſhire*, are in no reſpect like thoſe of either Place; theſe

Differences are ever to be cautiouſly weighed and conſidered, for they occaſion a different Method of Scrutiny and Examination, as well as a different Method of working; nor can we borrow any Light from our Neighbours into this Affair, the Picture muſt abſolutely be taken from the Original; therefore if any Author ſhould attempt to write a Treatiſe of this Art, and deſcribe the particular Method of working which ought to be purſued in a particular County or Soil, before he can pretend to render ſuch an Undertaking compleat and beneficial to the Inhabitants and Proficients of the Place he deſigns it for; he muſt ſurvey the mineral Mountains very carefully, that he may be able to compoſe his *Geographia Subterranea* in a correct and skilful Manner; for if this is not done, how can he be ſuppoſed to form his Maps exactly true? How will he be able to deſcribe the labouring Part? How will he be capable of diſtinguiſhing the promiſing Symptoms from thoſe that are otherwiſe? How will he maniſeſt the Sufficiency and Deficiency of the Produce of the Mountains, and point out the Way by which they may be worked to the beſt Advantage? Yet all theſe things muſt be diligently obſerved, and punctually proſecuted; theſe Rules muſt be ſtrictly obeyed and purſued by every Writer that deſigns his Labour to Benefit the Nation, to ſerve the Proprietor, and to inſtruct the Ignorant.

rant. In fine, he muſt follow the Example of the nice Court Surveyor, that not only points out the ſafeſt Roads and Harbours, but likewiſe manifeſts the dangerous Sands and Rocks; therefore let the *ſubterranean Geographer* deſcribe the barren as well as the fertile Mountain, for by that he will give us to underſtand the promiſing Ore bearing Signs, and *vice verſa*; for a good Guide ought not only to be acquainted with the main Road through which he is to conduct his Traveller, but he ſhould alſo know the bye ones, that he may not be at a Loſs to get into the main one, if by any Accident he ſhould happen to be thrown out of it.

*6thy*, When he comes to the ſmelting Part, he muſt lay down a general Hiſtory of the Produce of Nature in the Caverns of the Earth; he muſt give us a Deſcription of the various Sorts of Ores and Minerals, by ſhewing us not only the different Properties which eſſentially diſtinguiſh one Species from another, but likewiſe the Diverſity that may be found in each Specie; theſe, according to their ſeveral Degrees and Natures, are to be diſtributed into proper Claſſes, divided and ſubdivided under proper Heads; giving to each its inſeparable Characteriſticks, whereby to diſtinguiſh it from the reſt; telling us how and where they are commonly found, what

Appearances they afford when analyzed; what Principles they are compoſed of; what mixed Bodies they are incorporated with; what Compoſitions and Fluxes are moſt ſuitable to them, to free them from other heterogeneous Mixtures, and ſet at Liberty their pureſt Contents: In fine, it muſt be told after what Manner they are to be treated, and what Diſcoveries have been made in this Reſpect in different Ages; exhibiting exact Draughts of Furnaces that are and have been uſed in foreign Countries as well as here, that Choice may be made of thoſe that are the moſt fit and proper for the Purpoſe; pointing out their Advantages and Diſadvantages, Perfections and Imperfections, that they may be farther improved, as the Artiſt ſhall find Room, and have Occaſion.

*7thly*, The *Mine* and *Mineral Manufactures* are fully to be treated of, as *Arſenic*, *Spelter*, *Stone-blue*, and ſuch other valuable Commodities; the Materials that theſe are compoſed of muſt be made known; how they are produced, and after what Manner they are obtained in foreign Countries, even in the common Way of Smelting, muſt be clearly ſet forth: Theſe would make a conſiderable Article in the Trade and Manufactures of this Kingdom; for the Materials of the ſaid Commodities are to be met with in great Abundance in ſeveral Parts of this Country; but they are thrown away and neglected, as I have obſerved to you before.

8*thly*, The whole Work muſt be concluded with giving compleat Inſtructions on the Art of *aſſaying metalline* and mineral Ores in ſmall Quantities; nothing here ſhould be omitted, which can in any Shape be conducive to this Purpoſe, for it is of very great and material Concern: Here ſome Things may be taken notice of which I have mentioned in my former Letters; but will omit them, as they will naturally occur to an Author that is qualified for this Undertaking, or that is capable of framing a compleat Syſtem of Mining and Smelting.

If a Treatiſe ſhould be executed, that laid out a plain Plan, founded upon a ſolid Theory, the Whole confirmed and eſtabliſhed by Experiments, it might reaſonably be expected, that Mining and Smelting would undoubtedly raiſe their Head; it might juſtly be concluded, that theſe two Arts would ſoon come into a flouriſhing State in this Kingdom; that they would, in a few Years, gain the Aſcendancy in many Particulars, even over thoſe where the Mines are worked to the greateſt Perfection yet known. But, as I am ſenſible you are a true Patriot to your Country, and earneſtly deſirous to promote what will contribute to its Welfare, I muſt repreſent to you the Difficulties which I think will neceſſarily attend the Proſecution of what you have required of me, and which I have endeavoured to acquaint you with.

1ſt, Where is there a proper Perſon who will undertake this Affair, who will go through with the Labour, and bear the Expence of it? Or, by what other Means, in caſe he is not able, will the Expence of it be bore? For I judge it will take up any one, at leaſt, three or four Years to compleat ſuch a Work, and even during thoſe, muſt his whole Time be intirely engaged; the ſurveying Part will in particular be very tedious as well as expenſive; for though the Surveying five or ſix Counties in *Wales*, and about half the County of *Cornwall*, will, I think, be ſufficient to eſtabliſh ſuch Rules as will anſwer for the other Parts of the Kingdom; yet, to execute this in the Manner it ought to be done, will take full two Years.

2*dly*, Should the *Government* or the *Parliament* take this Affair into Conſideration, or any ways be willing to encourage an Undertaking of this Nature, I cannot pretend to ſet forth in what Manner this ought to be done, becauſe Lead, Tin, Copper, and Iron Mines, are private Properties; and how thoſe Proprietors are to b brought to concur with the Prerogative or Legiſlators, I cannot determine.

3*dly*, It can hardly be expected, that an Undertaking of this Nature ſhould meet with any Encouragement from the Proprietors, whoſe Diſpoſitions, and particular Intereſts are ſo various, that it would take up a Man's Age to bring a ſufficient Number of them to any tolerable Agreement for carrying on ſo uſeful an Affair; nor can there be any thing better expected, I am afraid, from the mineral Companies of this Kingdom.

4*thly*, But ſhould it happen that theſe Companies, and other publick-ſpirited Men, would enter into a Subſcription to carry on this Affair; by what Means could they obtain Leave, to ſurvey and examine the Mountains and Lands which would be requiſite to make ſuch a Work perfect and compleat, as they are oftentimes the Property of ſeveral Perſons? And though one or more of the Owners or Proprietors would give Leave for this Purpoſe, yet it might perhaps happen to be oppoſed by others; which would fruſtrate ſuch a good Intention, notwithſtanding it undoubtedly tended to the Advantage of all.

5*thly*, Suppoſing it were poſſible, without the Helps I have mentioned, that a ſufficient Collection of Materials could be obtained for this Purpoſe; and that all the other Obſtacles were removed, which might impede a Work of this Nature, what Bookſeller in this Kingdom would undertake to publiſh it? As it would, when compiled, if I rightly apprehend, make up, at leaſt, four Volumes in Folio; which, with the Copper Plates neceſſary for the Explanation of the Inſtruments and Materials, would amount to more than two hundred and fifty Sheets; and, if printed, how could it be vended to any Profit, eſpecially when ſo very few of the Operators are able to purchaſe ſuch a Performance?

*6thly*, Were all theſe Difficulties removed, and the Undertaking encouraged, either by the Government, Parliament, private Perſons, Proprietors, or in what other Manner ſoever: Where is the Man, at this Time, that is ſufficiently qualified for it? Who can ſtand the Teſt, or go through with the Examination requiſite, to prove his Abilities ſufficient for the Deſign? For theſe muſt needs be a ſufficient Satiſfaction given, before any one ſhould be intruſted in ſuch an important Work, or be permitted to uſher it into the World. What Miſchief would it not occaſion, if an unfaithful or an unſkilful Perſon ſhould be employed in it? And what Mortification and Diſappointment would it not be to all who are deſirous to promote the Good of this Country?

*7thly*, Should an able Hand, a Perſon duly qualified, be found out, and willing to undertake it, and compleat it in the Manner propoſed; what Encouragement ſhould be offered ſuch a Perſon, who muſt diveſt himſelf of all other Employments, to carry on and execute this great Taſk? I think a proper Penſion ſhould be propoſed and ſettled on him for Life, on his finiſhing and publiſhing the Work.

There is one Thing more I would adviſe, which would be an exceeding great Help to forward and compleat this Performance, and would effectually lay down a Foundation for advancing this Science to the greateſt Perfection; that is, to introduce on this Occaſion ſix or ſeven Youths, as Students, to be educated in this Science, and to be under the Care and Direction of the Undertaker of this Work, with him to go through the whole Performance, and the Proceſſes neceſſary for explaining it; by this Means they would become Maſters of the moſt abſtruſe Parts of this Science; they would gain a familiar Acquaintance with the practical Part, and ſo be thoroughly qualified to hand it down to Poſterity.

Perhaps other Difficulties may attend this Undertaking, which I am not at preſent aware of, which may prevent its being brought to paſs in any Time: However, I ſincerely wiſh it may be happily accompliſhed for the Good of the Country, of which I am now a Member, and that it may meet with all the Succeſs that can be deſired, or the Thing itſelf will admit of; for although the Ranges and Rakes of the Mountains are not of that Extent and Magnitude as thoſe on the Continent, yet many Parts of theſe Iſlands are ſo well ſtocked with Minerals and Foſſils, that they may be made ſufficient to convey one of the greateſt Benefits the Land can poſſibly produce to the lateſt Poſterity. I am,

*SIR,*

*Your moſt obedient Servant,*

DIEDERICK WESSEL LINDEN.

Holywell, *Nov.* 28,
1749.

# LETTER IV.

*Contains an important Diſcovery for the Improvement of Worm-Pitch, with Tales for the better Security of Ships Bottoms.*

SIR,

MY Reſidence in this Kingdom has given me frequent Opportunity of diſcourſing with different Perſons concerned in preparing *Pitch* for the Security of Ships Bottoms againſt Worms, and from thence it is vulgarly called *Worm-pitch*; but ſo ineffectual are their beſt Methods, that all of them acknowledge, they cannot find out any Mixture that will ſo cohere with the *Pitch* to the Wood, as to be a ſufficient Guard againſt thoſe pernicious *Animals*; and therefore thought proper to conſult me, whether there was any chymical or natural Body, on being mixed with *Pitch*, would ſo cohere to the Wood, as not to be deſtroyed or injured by any Sea-water, and rendered impoſſible for the Worms to penetrate through it. This appearing to me a Matter of the greateſt Conſequence, put me immediately upon Inquiry, what were the Ingredients they had hitherto made uſe of in their Mixture with the *Pitch*; and the beſt Information I could get was, that it conſiſted of Chalk, Brick-duſt, the *Caput mortuum* of Iron Vitriol (which is an Earth of a reddiſh-brown Colour) Soot, powdered

Glaſs, and many other Things of the like Nature belonging to the mineral Kingdom; theſe are all, or in Part, made uſe of in their preſent Mixtures, according to the different Fancy of the Preparer, without Regard to any exact Quantities of each; and, indeed, they are ſo candid, as to freely own, that they are far ſhort of being arrived at any tolerable Perfection in this Art.

Being thus acquainted with the Ingredients of which this *Worm-pitch* was compoſed, I took no ſmall Pains thoroughly to weigh and conſider the Nature of this Affair as far as I was able: Firſt I examined the Bottoms of ſome Ships that had been *pitched*, and were eaten into by the Worms; when I eaſily perceived that the Salt-water had diſſolved all the mineral Ingredients that were mixed with the *Pitch*, by which Means the Parts of the whole Mixture were diſunited, and an Opening made to the Wood, ſo that the Worms could immediately come at it without any Obſtruction; hence it appears, that the *Pitch* requires ſuch a Mixture as is indeſolvable, whoſe Parts will not be diſſolved or divided by that grand Menſtruum the *Sea-water*: After mature Conſideration of this Matter, I bent my Thoughts on *Talc*, as well knowing no Methods have been yet found out, either with Fire or Water, or any chymical Operations, that were able to diſſolve it; which is a plain Indication to me, that if the Powder of this Foſſil only was mixed with the *Pitch* inſtead of the other Ingredients above-mentioned, it would be a perfect ſafe-guard to the Ships, ſo as to ſecure them againſt thoſe pernicious Animals the Worms; which not only endanger the Cargo and lives of Men, but are alſo no inconſiderable Loſs to the Owners of Ships.

Having thus ſettled the Theory of the Matter, I proceeded to the experimental Part, being ſtrongly ſollicited and encouraged thereto by an eminent Surgeon that lived in a Sea-port Town in this Kingdom; at his earneſt Requeſt I mixed up a few Pounds of *Pitch* with powdered *Talc*; which he accordingly ſpread on a Piece of Timber, in like manner as is done on the Ships Bottoms, with their other Preparations; and more effectually to try the reſiſtive Power of this Ingredient when only uſed with the *Pitch*, he took the ſame Quantity as to Weight of the common Preparation of *Pitch* with Brick-duſt, and the other Compoſitions as before-mentioned, and ſpread that alſo upon another Piece of Timber, in like manner as the firſt; both theſe Pieces of Wood were put into the Sea together, ſecured ſo as to prevent their floating away; when, taking them up at the End of three Months, he found that the mineral Contents of that which was prepared in the common Way were all diſſolved, by which Means the Cement was looſened, and, in many Places, the Wood quite uncovered; but that on which the powdered *Talc*, mixed only with *Pitch*, was put, remained whole and intire as when put in, and ſo continued after it had been expoſed for ſome Twelve-months in the Sea, without any the leaſt Alteration whatever; and, undoubtedly, would have remained ſo much longer, had he not thought this a ſufficient Trial beyond all Contradiction.

It is ſome Years ſince the above Experiment was made, and it being at my firſt coming into this Kingdom, I had but very little Knowledge what Foſſils this Iſland contained, at leaſt I never had heard to that Time that it produced *Talc*; ſo that this Diſcovery, howſoever great and uſeful it might be, fell vaſtly ſhort of the real Satisfaction it would have given us, when we conſidered how difficult, if not impoſſible, it would be to prevail on the Ship-mechanicks to fetch Talc from *Italy*, and other Parts Abroad, where they have it in great Plenty; though this might have been done at a ſmall Expence, and to the greateſt Advantage, eſpecially when we conſider of what prodigious Importance it is to a

Nation like this, whoſe naval Commerce is ſo vaſt and extenſive; the more ſo, as it might be taken in as Ballaſt, and brought into this Country at a very ſmall Freight: But extraordinary Diſcoveries like this that bear the Name of an Invention, and where there are no experimental Evidences given, ſeldom meet with any tolerable Encouragement from the Vulgar; almoſt every one being unwilling to riſque the firſt Trial, which, in many Caſes, has been attended with innumerable Inconveniencies, when it has proved abortive.

I ſay, being diſcouraged by theſe Conſiderations, it prevented at that Time our making it known to the Publick, as it had no Probability then of any thing better than a curious Experiment; and, doubtleſs, would have been buried in Oblivion (the undeſerved Fate of many valuable Diſcoveries for want of proper Encouragement) had I not in a late Tour through *North Wales* diſcovered great Plenty of this valuable Foſſil called *Tale*. Mr. *Hill,* in his Hiſtory of Foſſils, tells us, there are conſiderable Quantities of it in many Parts of *Great Britain*; and in particular mentions the Places where it is to be found, in his Book, *p.* 71 to 75; ſo that preparing *Worm-pitch* with powdered *Tale*, will not in any Reſpect be more expenſive than their common Ingredients now in uſe; as it may be had at a very ſmall Price, and but little Trouble in raiſing; therefore I heartily wiſh that thoſe, whoſe Buſineſs it is to prepare *Worm-pitch*, would introduce this in the room of their preſent Method.

I apprehend no Objection can ariſe as to the Difficulty of this Preparation, when I ſay, that the ſame Quantity in Weight of *Tale*, muſt be mixed with the *Pitch* as they now make uſe of in their many various Compoſitions; which laſt muſt be all left out, and the *Tale* only put inſtead thereof.

All the Sorts of *Tales* mentioned by Mr. *Hill*, *p.* 71 to 75, are equally good for this Purpoſe, as alſo thoſe mentioned by that ingenious Gentleman *p.* 76 to 88, or all ſuch as the chymical Operations have no effect upon; and, as I am morally certain it will anſwer all the Ends propoſed, I doubt not of ſeeing the Time when it will be introduced into the Royal Navy, to the no ſmall Advantage of the Government, and the Nation in general; as doubtleſs, if it ſucceeds, it will be attended with the ſaving of many thouſand Pounds annually to this Kingdom.

The only Objection I can perceive may ariſe againſt this Propoſition is, the Difficulty there will be in reducing *Tale* into a Powder; but this may be eaſily removed, by erecting proper Machines to grind it in a raſp-like Manner; to which Water muſt be conveyed, for its more eaſy Reduction; after it is thus powdered by Means of the Machine and Water, it muſt be taken out and made perfectly dry, before it will be proper for mixing with the *Pitch*. The above Method will by no Means be tedious or expenſive, as by good Management ſome Tons a Day may be reduced into Powder.

There is a Foſſil generally called *Aſbeſtus*, which by ſome is ranked amongſt the *Talcs*, without any Diſtinction; to which, indeed, at firſt Sight, it bears a near Reſemblance, Part of its Contents being a Sort of *Talc*, and may in ſome Reſpects be rendered ſo, by reducing it into Powder, and then waſhing all its earthy Parts away, which are of a ſtone, gritty Nature, and by much the greateſt Part of the Whole; where genuine *Talc* is not to be had, and *Asbeſtus* is found in Plenty, I would recommend that to be uſed inſtead thereof; but not without being thoroughly cleanſed, as above, from all earthy Parts, before it is mixed with the *Pitch*, otherwiſe it will fail of the End propoſed.

Thus, Sir, you have the whole of my Diſcovery for the Improvement of *Worm-pitch*, which I thought incumbent upon me to acquaint you with, that it might be made publick; and ſhall think myſelf ſufficiently recompenſed, if, by this Means, it may be brought into uſe, be thought worthy the Notice of the Legiſlature, and meet with the deſired Succeſs; at leaſt, I am certain, there can be no Hazard in Trial, as I am well convinced, ſhould it fall any thing ſhort of what I aſſert, it will in no reſpect be inferior to their preſent Preparations; therefore cannot ſee any Objection there can be againſt trying the Experiment: I choſe to expreſs myſelf in this plain intelligible Manner, as it has generally been found to have more Weight with common mechanical People, by which Means many things have been brought into uſe, that could not have been effected by a Chain of the fineſt philoſopical Reaſoning.

It is my ſincereſt Wiſh, that this Experiment may become as general as it will be found uſeful, not regarding the Cenſure that may be caſt upon me by narrow-minded, avaritious Perſons, who will be ready to ſay, if it was capable of anſwering all the Ends I propoſe by it, it would be of ſuch prodigious Conſequence, that I might have raiſed from it a competent Fortune; but let it ſuffice, as an Anſwer to all ſuch Cavillers, that my preſent Situation in Life will not permit me to proſecute ſuch an Undertaking on my own Bottom, as it might be a Work of many Years, if not an Age, before one ſingle Perſon could in all Probability be able to bring it into general uſe : All I can do at preſent is to recommend it ; and, if found beneficial, ſome noble and generous Patriots (with which this Nation ſo remarkably abounds) may not think the Diſcoverer unworthy their grateful Acknowledgements. I am,

*SIR,*

*Your moſt obedient humble Servant,*

DIEDERICK WESSEL LINDEN.

Holywell, *Jan.* 6, 1749.

*FINIS.*